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REFERENCES

- Baird, I. M., and Podmore, D. A. (1954). *Lancet*, 2, 942.
 Beaujon, A. (1951). *Rev. Policlin. (Caracas)*, 19, 485.
 Cappell, D. F., Hutchison, H. E., Hendry, E. B., and Conway, H. (1954). *British Medical Journal*, 2, 1255.
 Dickstein, B., Wolman, I. J., Tan, C., Slaughter, B., Butson, H., and Cohen, R. (1952). *Amer. J. Dis. Child.*, 84, 52.
 Granrud, H., and Øster, J. (1950). *Nord. Med.*, 43, 468.
 Hagberg, B. (1951). *Acta paediat. (Uppsala)*, 40, 519.
 Haler, D. (1952). *British Medical Journal*, 2, 1241.
 Hanna, M., and Shehata, A. H. (1951). *Ann. paediat. (Basel)*, 176, 121.
 Jennison, R. F., and Ellis, H. R. (1954). *Lancet*, 2, 1245.
 Rossier, A., and Potiron, L. (1955). *Arch. franç. Pédiat.*, 12, 261.
 Schöner, W. (1952). *Wien. med. Wschr.*, 102, 718.
 Scott, J. M., and Govan, A. D. T. (1954). *British Medical Journal*, 2, 1257.
 Stransky, E., and Daus-Lawas, D. F. (1952). *Ann. paediat. (Basel)*, 179, 348.
 Wiesener, H. (1952). *Dtsch. med. Wschr.*, 77, 622.
 Wolman, I. J. (1953). *Quart. Rev. Pediat.*, 8, 11.

METABOLIC CHANGES AND THERAPEUTIC CONSIDERATIONS IN BILATERAL ADRENALECTOMY

BY

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The profound metabolic and circulatory changes produced by surgery and anaesthesia have been intensively studied in recent years. The metabolic aspect, in particular, has been investigated by Moore and Ball (1951), who correlated data of other workers in this field. The consensus of opinion is that hyperactivity of the adrenal cortex is responsible for the broad pattern of these changes.

The superimposition of bilateral adrenalectomy upon a surgical procedure would thus produce further problems and difficulties to the body economy worthy of study.

Clinical Material and Methods

Three consecutive patients with carcinoma of the breast and widespread metastases admitted for simultaneous bilateral adrenalectomy and oophorectomy were considered. Each had had a radical mastectomy; all had been treated with prolonged androgen therapy.

After haemoglobin, protein, and electrolyte deficiencies had been corrected, the patients were prepared for operation by the regime advocated by Hollander *et al.* (1952). The details of cortisone, deoxycortone acetate (D.C.A.), and salt administration, which were started the day before the operation, are shown in Fig. 1. Each patient was taking fluid by mouth on the first day after operation and a normal diet on the seventh day. Accurate fluid balance charts were kept throughout the patients' stay in hospital.

The investigation started two or three days before the operation and lasted until the patients were discharged three weeks later. Urine analysis included volume, specific gravity, sodium, potassium, chloride, creatinine, urea, and ammonia. Routine clinical laboratory methods were used throughout, save for creatinine, which was estimated by the method advocated by Brod and Sirotta (1948). The glomerular filtration rate was calculated as 24-hour endogenous creatinine clearance. The percentage excretion of water,

sodium, and potassium was calculated according to the method of Platt (1950). The potassium/nitrogen ratio was calculated from the sum of the urea, ammonia, and creatinine nitrogen found in the 24-hour urine specimen.

Blood chemistry included haematocrit and the plasma content of sodium, potassium, chloride, CO₂ combining power, creatinine, and urea. The intracellular sodium, potassium, and chloride were calculated from the formula:

$$C_o = \frac{C_b - C_p (1 - Ht)}{Ht}$$

where C_o, C_b, and C_p are the concentrations of sodium, potassium, or chloride in the cells, whole blood, and plasma respectively in mEq/litre, and Ht is the haematocrit expressed as a fraction of whole blood. Since the completion of this paper it has been brought to our attention that a similar formula, but with an obvious printer's error, had been derived by Eliel and Pearson (1951).

Results

Our results after adrenalectomy are similar in pattern to, but different in detail from, those found in non-adrenalectomized patients after surgery and anaesthesia. The data are presented in three phases.

(1) Period of Sodium Retention

On the first day after the operation the concentration of urinary sodium was decreased in one patient and was the same as the controlled pre-operative level in two. After this the concentration of sodium in the urine decreased in the subsequent 24-hour periods, reaching its minimum value approaching zero in two patients on the fifth day, and in one patient on the third day after operation—average four days (Figs. 1 and 2). The potassium excretion in the three patients averaged 44 mEq/day for the first three days after

TABLE I.—Case 3, aged 56. Bilateral Adrenalectomy and Oophorectomy. Detailed Constituents of the Three Periods of Sodium Excretion

Day	Urine Vol. ml./24 hr.	Sp. Gr.	% Excretion Na*	% Excretion K†	% Excretion H ₂ O‡	G.F.R. Cr. ml./24 hr.	K/N Ratio
-1	1,380	1.016	1.35	23.5	2.45	39	6.2
Period of Relative Na Retention	0		Operation				
	1	500	1.030	0.60	23.6	32	6.5
	2	790	1.022	0.20	24.2	62	5.5
	3	500	1.024	0.07	21.2	42	4.0
	4	1,215	1.012	0.05	11.5	97	3.1
Period of Early Na Diuresis	5	560	1.012	0.14	17.0	39	4.2
	6	1,475	1.010	0.32	15.0	146	3.8
	7	1,255	1.012	0.56	20.8	146	4.9
	8	1,405	1.008	0.90	8.0	176	2.1
	9	1,480	1.010	1.00	12.5	154	3.0
Period of Relative Na Retention	10	1,740	1.012	1.82	15.2	224	6.5
	11	1,905	1.012	1.55	17.4	227	6.9
	12	1,865	1.012	0.95	19.0	186	4.9
	13	2,350					
	14	1,640	1.008				
Period of Late Na Diuresis	15	1,340	1.010	0.70	15.5	150	4.6
	16	1,655	1.020				
	17	1,380	1.014	0.72	21.2	140	6.1
	18	1,580	1.016				
	19	1,630	1.014				
Period of Late Na Diuresis	20	1,630	1.012	0.92	24.5	180	7.7
	21	1,330	1.012	0.91	24.2	162	7.3
	22	1,115	1.013	0.91	22.0	148	6.3
	23	2,695	1.012	2.25	23.2	286	6.2
	24	1,800	1.014	1.80	23.0	233	5.8
Period of Late Na Diuresis	25	2,500	1.008	2.33	35.0	350	6.0
	26	2,100	1.013	1.95	31.0	256	6.0
	27	2,000	1.013				
	28	2,625	1.014				
	29	1,405	1.016				
30	1,620	1.008				78	9.5

* $\frac{U.Na \times P.cr.}{P.Na \times U.cr.} \times 100$. † $\frac{U.K \times P.cr.}{P.K \times U.cr.} \times 100$. ‡ $\frac{P.cr.}{U.cr.} \times 100$.

§ The period of relative sodium retention occurred in all three patients. It may, however, be the result of random variation rather than a true period, characteristic of adrenalectomized patients (see Table III and discussion).

TABLE II.—Case 2, aged 43. *Bilateral Adrenalectomy and Oophorectomy*

Day	Urine Vol. ml./24 hr.	Sp. Gr.	% Excretion Na*	% Excretion K†	% Excretion H ₂ O‡	G.F.R. Cr. ml./min.	K/N Ratio
Pre. Op. Period							
-3	1,240	1.008	1.37	13.3	2.75	37	3.8
-2	1,500	1.006	1.50	21.5	3.60	39	5.2
-1	653	1.010	1.71	25.0	2.50		6.4
Period of Na Retention							
0	1,240	1.017	0.51	18.6	1.05	78	
1	1,830	1.012	0.01	12.2	1.05	120	2.9
2	1,540	1.010	0.05	12.2	1.60	85	2.9
3							
4	1,600	1.009	0.28	14.5	1.75	85	4.1
5	1,290	1.009	0.25	12.2	1.85	60	3.8
6	1,135	1.009	0.42	11.5	1.90	55	3.0
7	1,050	1.008	0.97	12.8	2.00	46	
8	1,700	1.010	0.91	10.7	1.65	59	3.1
9	1,700	1.010	1.24	12.6	2.20	64	4.0
Period of Late Na Diuresis							
10	1,550	1.008	1.21	28.7	2.00	67	8.7
11	1,500	1.011	1.17	22.2	1.45	88	7.3
12	1,340	1.010	1.78	31.3	2.20	52	8.7
13	1,420	1.010	1.20	36.7	2.10	62	9.0
Period of Relative Na Retention							
14	1,400	1.009	1.39	19.5	2.30	54	4.4
15	2,040	1.006	1.13	19.5	2.60	70	5.4
16	1,970	1.010	1.04	19.6	2.00	90	4.7
17	2,250	1.009	1.52	16.0	2.50	75	5.3

* $\frac{U.Na}{P.Na} \times \frac{P.cr.}{U.cr.} \times 100$. † $\frac{U.K}{P.K} \times \frac{P.cr.}{U.cr.} \times 100$. ‡ $\frac{P.cr.}{U.cr.} \times 100$.

§ The period of relative sodium retention interrupts the period of late diuresis.

G. NaCl. I.V. & ORAL EXCLUSIVE OF DIET.

operation, and 55 mEq/day for the whole period of sodium retention, as against 45 mEq/day in the pre-operative period. During the period of sodium retention the specific gravity of the urine increased and was considerably higher than in the pre-operative period. In two patients the urine volume reached pre-operative values on the first day after operation, and in the third patient only on the fourth day.

There was a marked decrease in the percentage of water and sodium excretion on the first day after operation, while the percentage figure of potassium excretion remained at or slightly below pre-operative values. These values decreased until the peak of sodium retention on the fourth day after operation and then slowly approached pre-operative values on the ninth and tenth day after operation. The creatinine clearance in the pre-operative period in our patients averaged 38.5 ml./min. There was a marked increase in the glomerular filtration rate to double this value during this period. The glomerular filtration rate varied with the urine flow.

The potassium/nitrogen ratio averaged 5.9 during the pre-operative phase. After operation it was reduced, and remained below the pre-operative value until late into the sodium diuresis phase. This fall in potassium/nitrogen ratio in the early days after operation was maintained in spite of liberal salt supplementation (Tables I and II).

During the same period the nitrogen excretion rose from a pre-operative average of 8.5 to 21.9 g. a day, indicating an increased catabolic process.

In each patient the plasma sodium fell during the period of sodium retention (Fig. 2). In two of the three patients studied the plasma potassium fell below the pre-operative level, and hypokalaemic alkalosis developed. At the same time the blood urea rose sharply above the pre-operative

FIG. 2.—Case 2, aged 42. Showing the paradoxical relationship between the plasma sodium levels and urinary excretion of sodium. The plasma level of sodium rises as the excretion of sodium rises and falls when the urinary excretion of sodium falls. This phenomenon was noted during the period of sodium retention in patients undergoing surgical procedures other than adrenalectomy (Moore and Ball, 1951). In our patients this "paradoxical sodium level" persisted throughout the period of study.

FIG. 3.—Plasma electrolyte changes in Case 1 following bilateral adrenalectomy and oophorectomy.

(2) Period of Early Sodium Diuresis

In the period of early sodium diuresis the glomerular filtration rate is double pre-operative values and still tends to follow the volume of urine excreted (Tables I and II). The percentage excretion of water, sodium, and potassium tends to remain slightly below the pre-operative level. The potassium/nitrogen ratio is well below the pre-operative level during this early period of sodium diuresis. A sodium

level in each patient, and remained elevated until the peak of sodium retention was reached, and then fell to normal with the onset of diuresis.

The rise in blood urea, simultaneous with the fall in haematocrit value, in the face of an increased glomerular filtration rate and increased excretion of urea is another indication of increased catabolism (Fig. 3).

rate still follows, but not as strictly as in the earlier periods after operation, the volume of urine excretion. It will be noted that there is a tendency for the urine specific gravity to rise with increased urine flow (Tables I and II).

During both periods of sodium diuresis the urine sodium concentration and the amount of sodium excreted in 24 hours is proportional to the urine flow (Fig. 4).

During the periods of sodium diuresis the plasma sodium levels increased. In Case 2 the plasma sodium rose from a level of 140 mEq/l. at the peak of sodium retention to 153 mEq/l. in the phase of early sodium excretion, and to 156 mEq/l. during the peak of late sodium diuresis. A similar pattern was followed in the other two patients (Fig. 2).

The blood urea returned to the pre-operative level during the phase of early sodium diuresis, but rose above the pre-operative values in the late phase of sodium diuresis (Fig. 3).

Intracellular Sodium and Potassium

The shift of sodium and potassium across the red blood cell membrane is consistent with the paradoxical plasma sodium values (Table III).

During the period of sodium retention the sodium content of the red blood cell remains constant or below pre-operative values. At the same time there is a sharp fall in the haematocrit reading.

During the period of sodium diuresis the concentration of intracellular sodium is markedly reduced. This coincides with the raised plasma sodium found during this period.

During the brief periods of late sodium retention which punctuate the period of sodium diuresis the intracellular sodium is raised coincidentally with a fall in plasma sodium. The intracellular potassium concentration is reciprocal with the sodium changes.

Discussion

The fact that patients subjected to adrenalectomy and patients subjected to operations other than adrenalectomy develop a similar urinary excretion pattern of sodium retention and increased potassium and nitrogen excretion suggests that in both groups anaesthesia and operation occasion a primary metabolic disturbance. This results in the enlargement of the extracellular space and a consequent fall in haematocrit reading and plasma sodium (Elman *et al.*, 1949; Wilkinson *et al.*, 1951; Conway and Hingerty, 1953).

After an operation other than adrenalectomy the patient reacts to this disturbance by adrenocortical hyperactivity (Moore and Ball, 1951; Elman *et al.*, 1952).

The reversal of the potassium/sodium ratio is characteristic of adrenocortical activity on the kidney tubule (Tait *et al.*, 1952; Elman *et al.*, 1952). Elektrocorone (Von Pesaulles *et al.*, 1953) or aldosterone (Simpson *et al.*, 1953) causes a renal leak of potassium, together with sodium retention. The reversal of potassium/sodium ratio in our patients is effected by a constant excretion of potassium compared with pre-operative values, and an increase in sodium retention. It has been suggested by Winter *et al.* (1938) that the posterior pituitary is responsible for the fall of serum

FIG. 4.—Correlations between the urine volume per 24 hours and the mEq of sodium excreted during the periods of sodium diuresis in the three patients studied. The similarity to the data obtained by Burstson and Garrod (1952), who studied the relation between urine volume and daily chloride excretion in patients with Addison's disease adequately treated with cortisone, is striking.

The potassium/nitrogen ratio during this period rose to above the pre-operative level and to values much higher than those found during the early phase of sodium diuresis. During the late phase of diuresis the glomerular filtration

(3) Period of Late Diuresis

The period of late sodium diuresis is characterized by an increase in the percentage excretion of water, sodium, and potassium equal to or above the pre-operative figures, with a maintenance of the high glomerular filtration rate.

TABLE III.—The Data Listed under Period of Relative Sodium Retention is a Composite Compiled from such Periods Regardless of whether they Occurred in the Period of Early or Late Diuresis

	Case No.	Pre-op. (Days)			Period of Early Na Retention (Days)					Period of Early Na Diuresis (Days)							Period of Relative Na Retention (Days)			Period of Late Na Diuresis (Days)	
		3	2	1	2	3	4	5	1	2	3	4	5	6	7	1	2	3	1	2	
Haematocrit	1 2 3	40	35 40 48	40 40 49	40 40 49	35 35 49	35 34 39	33 40	35 40	35 34 44	34 34 44	33 37 41	34 37 38	34	33 33 38	33 33 34	33 34	34 33 44			
Intracellular Na (mEq/l.)	1 2 3	23	18 19 24	19 19 15	5 19 10	10 19 8	18 19 16	24	18 5	8 5	7 6 0	17.5 0	22.5		30 30 13	30 19 36	36	6 1 0			
Intracellular K (mEq/l.)	1 2 3	111 115 106	115 106	110 104 106	113 104 103	102 105 106	105 105 105	105	113 117	112 114 109	108 106 106	110 110 110			114 114 106	114 117 108	117 108	105 115 113			

sodium after operation. LeQuesne and Lewis (1953), LeQuesne (1954), and Dudley *et al.* (1953) have shown that there is a brief period, of some hours, of sodium and water retention with a urine of high specific gravity after operations other than adrenalectomy, and that this is the result of an increased posterior pituitary activity. Then follows a normal or increased production of urine which is characteristic of marked adrenocortical activity. Elman *et al.* (1949) reported after operations other than adrenalectomy a decrease in urinary specific gravity on the first day which persisted for several days in spite of a daily fluid intake of 2,000 ml. Our patients showed an increased urinary specific gravity during the complete period of sodium retention which lasted up to five days, in spite of an adequate urine output (Tables I and II).

The prolonged period during which the specific gravity of the urine of our patients remained high on an average intake of 2,200 ml. of water a day could be explained by the increased percentage water retention (pitressin), a simultaneous increased glomerular filtration rate (cortisone), plus a salt-retaining factor. The latter is under investigation. It may well be due to the anterior pituitary (Stein *et al.*, 1952) or pitressin itself (Hollander *et al.*, 1952). This combination of hormones would thus simulate increased adrenocortical activity by producing an adequate volume of urine with a high K/Na ratio.

Moore and Ball (1951), Elman *et al.* (1952), and Randall *et al.* (1949), writing on post-operative potassium deficiency in patients after surgery other than adrenalectomy, stated that the rise in potassium/nitrogen ratio in their patients was the result of increased adrenocortical activity. In our patients the potassium/nitrogen ratio fell. After the first three days following operation our patients were not on a controlled nitrogen diet. However, since ordinary dietary variations can only cause an increased potassium/nitrogen ratio, the low potassium/nitrogen ratio found in our patients is taken to indicate an absence of adrenocortical activity. That a profound catabolic process did occur during the phase of sodium retention is indicated by the threefold increase in nitrogen excretion during this period.

Fourman (1952) has shown that D.C.A. produces a fall in serum sodium and an expansion of the extracellular space in patients with Addison's disease. Conway and Hingerty (1953), studying rats after bilateral adrenalectomy, recorded a decrease in serum sodium after operation which was greatly magnified by the administration of D.C.A. but abolished by cortisone. It would seem that the use of D.C.A. in the period of sodium retention is unnecessary or may even be harmful. Should the decrease in plasma sodium indeed be the prime mover in causing sodium retention, D.C.A. could prolong the period of sodium and water retention at a time when catabolic processes are increased. Butler *et al.* (1953) studied two cases of bilateral adrenalectomy, one with and one without D.C.A., and drew the clinical impression that D.C.A. was unnecessary. Kreiger *et al.* (1953) studied five patients and accords with this view. We have since this study observed three patients subjected to adrenalectomy without D.C.A., and noted that the mineral excretion pattern was identical with this series.

The close relationship between the glomerular filtration rate and the 24-hour urine volume during the period of sodium retention in our patients resembles the findings of Burston and Garrod (1952), who established this direct relationship between glomerular filtration rate and urine flow in patients with Addison's disease before treatment with cortisone. Treatment with cortisone in their patients raised the glomerular filtration rate and established a direct linear relationship between urine flow and chloride output. A relationship of this kind was present in our patients in the late diuretic phase (Fig. 4). Thus our patients resemble cases of Addison's disease with inadequate cortisone therapy in the phase of sodium retention and the picture of adequate cortisone therapy in the phase of late diuresis, although the actual cortisone dosage administered was less in this phase (50 mg. per 24 hours) than in the phase of sodium retention (100 to 200 mg. per 24 hours).

That cortisone and antidiuretic substance (A.D.S.) can be antagonistic has been demonstrated (Eversole *et al.*, 1942; Hollander *et al.*, 1953). This relationship between A.D.S. and cortisone might explain the Addisonian features of the glomerular filtration rate noticed in our patients. It is also of clinical importance. A persistent low blood pressure, together with a scanty urine of high specific gravity, and especially if accompanied by abdominal pain, a raised temperature, high pulse rate, and vomiting, indicates inadequate cortisone therapy regardless of the sustaining dosage. We have seen four patients after operation with hypotension who did not respond to noradrenaline but who did respond to intravenous hydrocortisone.

The adrenalectomized patient differs from other surgical patients in that no period of convalescence restores a normal hormonal balance. Instead, a state is reached which is reminiscent of Addison's disease, modified by the administration of cortisone. The cortisone has the renal effect of increasing the glomerular filtration rate while maintaining the percentage excretion rate of water, sodium, and potassium above that of the earlier periods after operation.

The consequent excessive loss of sodium in proportion to urine flow is not reflected by the plasma sodium level, which remains high by reason of the shift of intracellular sodium into the extracellular space. The serum potassium, however, does fall. Large amounts of sodium may thus be lost without detection. The use of D.C.A. or the newer fluoro-hydrocortisone may prove beneficial in the late diuretic phase.

Conclusions and Summary

Patients undergoing major surgical operations other than total adrenalectomy show metabolic changes which are ascribed to adrenocortical hyperactivity. These are sodium retention, increased potassium excretion, high potassium/nitrogen ratio, and low specific gravity urine. The post-operative adrenalectomized patient mimics those metabolic changes. In the absence of adrenal glands these metabolic changes effected by increased pituitary activity modified by cortisone therapy are sodium retention, a constant potassium excretion, low potassium/nitrogen ratio, and high specific gravity urine.

Surgical patients other than those undergoing bilateral adrenalectomy enter a phase of diuresis after the period of sodium retention and then return to a normal pre-operative metabolic pattern. Adrenalectomized patients enter a phase of permanent sodium diuresis which is not unlike that of patients with Addison's disease adequately treated with cortisone.

The use of D.C.A. is probably unnecessary in the immediate post-operative period and may even be harmful. The use of D.C.A. in the period of sodium diuresis is discussed.

Adrenalectomized patients have an increase of anti-diuretic substance in the blood; this substance is antagonistic to cortisone. Signs of adrenal insufficiency, low blood pressure, abdominal pain, and scanty urine with high specific gravity and low sodium content demand increased cortisone therapy regardless of the maintenance dose.

REFERENCES

- Brod, J., and Sirota, J. H. (1948). *J. clin. Invest.*, 27, 645.
- Burston, R. A., and Garrod, O. (1952). *Clin. Sci.*, 11, 129.
- Butler, W. W. S., Greyhack, J. T., Ransom, C. L., and Scott, W. W. (1953). *J. Urol.*, 70, 657.
- Conway, E. J., and Hingerty, D. (1953). *Biochem. J.*, 55, 447.
- Dudley, H. F., Boling, E. A., LeQuesne, L. P., and Moore, F. D. (1953). *Ann. Surg.*, 140, 354.
- Eliel, L. P., and Pearson, O. H. (1951). *J. clin. Endocr.*, 11, 913.
- Elman, R., Lemmer, R. A., Weichselbaum, T. E., Owen, J. G., and Yore, R. W. (1949). *Ann. Surg.*, 130, 703.
- Shatz, B. A., Keating, R. E., and Weichselbaum, T. E. (1952). *Ibid.*, 136, 111.
- Eversole, W. J., Gaunt, R., and Kendall, E. C. (1942). *Amer. J. Physiol.*, 135, 378.
- Fourman, P. (1952). *Clin. Sci.*, 11, 388.
- Hollander, V. P., West, C. D., Whitmore, W. F., jun., Randall, H. T., and Pearson, O. H. (1952). *Cancer*, 5, 1019.

- Kreiger, H., Abbot, W., Levey, S., and Babb, L. (1953). *Surg. Gynec. Obstet.*, 97, 569.
 LeQuessne, L. P. (1954). *Lancet*, 1, 172.
 — and Lewis, A. A. G. (1953). *Ibid.*, 1, 153.
 Moore, F. D., and Ball, M. R. (1951). *The Metabolic Response to Surgery*. Thomas, Illinois, U.S.A.
 Platt, R. (1950). *Clin. Sci.*, 9, 367.
 Randall, H. T., Habif, D. V., Lockwood, J. S., and Werner, S. C. (1949). *Surgery*, 26, 341.
 Simpson, S. A., Tait, J. F., Wettstein, A., Neher, R., Euw, J. v., and Reichstein, T. (1953). *Experientia (Basel)*, 9, 333.
 Stein, J. D., Bennett, L. L., Batts, A. A., and Li, C. H. (1952). *Amer. J. Physiol.*, 171, 587.
 Tait, J. F., Simpson, S. A., and Grundy, H. M. (1952). *Lancet*, 1, 122.
 Von Pesualles, P., Tripod, J., and Schuler, W. (1953). *Schweiz. med. Wschr.*, 83, 1088.
 Wilkinson, A. W., Billing, B. H., Nagy, G., and Stewart, C. P. (1951). *Lancet*, 1, 315.
 Winter, C. A., Gross, E. G., and Ingram, W. R. (1938). *J. exp. Med.*, 67, 251.

BILATERAL ANTERIOR TRANSABDOMINAL ADRENALECTOMY

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Bilateral adrenalectomy is probably not, destined to remain a standard operation even for advanced and hopeless cancer of the breast, but exposure of the adrenal glands, and some form of bilateral adrenalectomy, is likely to remain a standard procedure for at least some varieties of adrenal disease. In both circumstances an anterior approach has many advantages. In adrenalectomy for cancer it is often dangerous to turn the patient to the prone position if the cervical spine is the seat of advanced disease; a hemiplegia has sometimes been produced by this change in position. When a patient undergoing adrenalectomy for cancer has a pathological fracture of the femur, the prone position is sometimes, at least, awkward. When the adrenal glands are exposed for disorders of adrenal function or for the suspicion of adrenal tumour, it is extremely convenient to present both adrenals simultaneously to close inspection, and this is possible in all cases, even if the actual removal of the right adrenal gland from the front proves to be difficult, as it sometimes does. The left adrenal can always be removed with greater facility from the front than from the back, and even if the right adrenal, having been clearly inspected, proves impossible of removal from the front, as it has not done in our hands, nothing would be lost then in removing it, or the greater part of it if that were desired, from the back.

Route of Approach

When the operation is done for advanced cancer, bilateral oophorectomy is usually done at the same time, and it is then convenient to explore the upper abdomen directly without change of the patient's position. The left adrenal is exposed and removed; the right adrenal is explored also. Theoretically, if the removal of the right adrenal offered insurmountable difficulty there would be no objection to closing the abdominal wound, turning the patient over, and completing the operation on the right side from behind. We have not found it necessary to do this in 12 successive cases in which we have performed the bilateral operation from the front. This anterior approach has two particular advantages in cancer cases. The upper abdomen can be fully explored for metastases, and outlying islands of

adrenal tissue, separate from the main gland, may easily be recognized and removed. On two occasions we have found accessory adrenal tissue in a low position in the retroperitoneum, where it would not have been detected by a posterior approach. The anterior approach gives a clear view of the retroperitoneal space on both sides.

Having now had experience of the anterior route, the posterior route, and the postero-lateral route, we can say that any of these routes may on occasion prove difficult, and we have not had greater difficulty with the anterior abdominal approach than with the posterior and postero-lateral operations. Indeed, it has been possible, when the operation has been performed from the front, to be more certain of removing both adrenal glands intact, with their borders and surfaces unbroken, and this is always a great assurance that the adrenalectomy has been complete. Left anterior adrenalectomy is a simple abdominal operation. In most, though not in all, cases right anterior adrenalectomy is a simple abdominal operation also. The advantages of the anterior route compensate for the technical difficulties which are sometimes met on the right side.

When the operation is performed for adrenal dysfunction, bilateral subtotal adrenalectomy is always possible and usually easy by way of the abdomen, and it is satisfying in such circumstances to have both adrenal glands displayed at the same time. When any other approach is used one never knows, before performing subtotal adrenalectomy on one side, whether there may not be a tumour in the other gland still to be explored. The simultaneous exposure of the adrenal glands by two separate posterior incisions is awkward and dissatisfying. When an adrenal tumour is suspected, the advantage again of exposing both adrenal glands simultaneously is very substantial and the removal of a tumour from either gland is always easily possible through the abdomen.

There are two details of operative procedure which facilitate the anterior operation. On the right side, mobilization of the spleen with the splenic vessels and the left end of the pancreas brings the left adrenal gland into clear view. On the right side, care is taken to draw down the kidney before opening the retroperitoneum; this usually fixes the adrenal *in situ*. If the peritoneum is opened, and the kidney then retracted downwards, the suprarenal does not always follow it. Indeed, it sometimes does not move down with the kidney at all.

Operative Detail

The incision is an oblique one parallel with and one hand-breadth below the right costal margin. From a point just lateral to the right border of the right rectus muscle, the incision is carried upwards and to the left to meet the left costal margin. The right rectus and its sheath are divided in the line of the incision, the linea alba is divided in the midline, and the left rectus and its sheath are divided also as far as the costal margin. The peritoneal cavity is opened. The spleen is mobilized as for splenectomy by an incision through the peritoneum just beyond its reflection from spleen to abdominal wall

(left or posterior layer of the lineal renal ligament). The retroperitoneal continuation of the transversalis fascia is divided in the same line, and the spleen is drawn forward and to the patient's right with the tail and body of the pancreas and the splenic vessel (Fig. 1). This immediately brings the left adrenal gland to

FIG. 1.—Traction on splenic artery fixes aorta, drawing it forwards and to patient's right, with renal artery, suprarenal artery, suprarenal nerves, and suprarenal gland.