HEDONAL AS A GENERAL ANÆSTHETIC ADMINISTERED BY INTRAVENOUS INFUSION.

A REPORT ON 75 CASES.

By CHARLES M. PAGE, M.S. LOND., F.R.C.S. ENG.,
RESIDENT ASSISTANT SURGEON, ST. THOMAS'S HOSPITAL.

THE induction of general anæsthesia by the intravenous injection of drugs was first effected in man in 1872 by Oré.¹ The substance employed was chloral. Fifty-three cases were reported, in 51 of which satisfactory results were obtained. Further experience, however, proved that the procedure was not without danger, and the method does not seem to have been further developed till 1909, when Burckhardt² published his application of the principle—chloroform first and then ether being the anæsthetics made use of. In the following year Professor Federoff, of St. Petersburg, suggested a trial of the intravenous administration of hedonal. Since 1900 this drug had had some vogue as a hypnotic; it had also been given by the mouth as a precursor of chloroform and ether in several Russian clinics with satisfactory results. Reports of its use as a general anæsthetic first appeared in Russian journals³; a preliminary note was published in German in 1910⁴; and in the following year Jeremitsch⁵ described the technique employed, giving details of 65 cases. At last year's Congress of the German Surgical Association Federoff⁶ contributed a brief account of 530 cases collected from three Russian clinics; no death directly attributable to the anæsthetic was reported among the series.

The method adopted is one of interrupted injections. A 0.75 per cent. solution of hedonal in normal saline solution is placed in a flask from which it can be forced by air pressure; leading from the flask is a long rubber tube terminating in a fine hollow needle; a superficial vein is exposed, punctured by the needle, and a volume of fluid sufficient to produce general anæsthesia is injected; the needle is then withdrawn and reinserted for the purpose of further injections as they become necessary. In the course of an operation lasting 1 hour and 51 minutes five such injections were required. In Jeremitsch's 65 cases the total amount of fluid injected in any one instance varied from 325 c.c. to 1100 c.c. In two cases satisfactory anæsthesia was not obtained: in one the vein isolated was very small and the injection was carried out with difficulty; in the other instance, a case of varicose veins, the injection was made into the internal saphenous, and anæsthesia was not induced after the injection of 800 c.c. of fluid; in consequence of this latter experience Jeremitsch advises against infusion into the veins of the lower extremity. The only complication of anæsthesia which he records is respiratory depression; this appeared in one of his cases and was attributed to a too rapid injection of the fluid. Federoff notes that respiration was affected in 8 out of 530 cases. Jeremitsch states that vomiting or headache was usually absent in the post-operative period; he detected no evidence of irritation of the kidneys, and had no case of local thrombosis in the veins.

Hedonal anæsthesia has been employed at St. Thomas's Hospital in about 200 cases; in all instances satisfactory anæsthesia has been obtained. The conclusions in this paper have been based on the first 75 cases. I have adopted a method of continuous gravity-fed infusion, which seems to be simpler and as efficacious as the method hitherto employed. Before going into details of the technique and the general results I will give some account of the characteristics of hedonal.

Properties of Hedonal.

Hedonal, or methyl-propyl-carbinol-urethane, has the following formula:—

It is a white crystalline solid, stable at ordinary temperatures, its solubility in water at 100° F. is 1 in 100, it readily

crystallises out of a saturated solution in long fine needles. The solution can be boiled without the properties of the drug being affected, but prolonged heating diminishes the concentration owing to the volatilisation of a certain amount of the compound. It does not appear to alter in composition when kept for some months in the dry state.

Experiments on animals by Dreser⁷ showed that hedonal had ten times the hypnotic effect of urethane and twice that of chloral; he found that the respiration was not materially affected in conditions of deep narcosis, and that it caused a slight fall in the blood pressure. He noticed that the drug had a diuretic action, which is attributed to the theory that in the body the substance breaks up into urea, carbon dioxide, and water.

Lampsakow (quoted by Krawkow⁸) carried out further experiments, and found that in dogs and rabbits a dose of 0.4 to 0.5 gramme to the kilogramme of body weight produced complete general anæsthesia; the respiratory and cardiac rhythm remained regular. If toxic doses were given the heart continued beating after paralysis of the vasomotor centre. He considered that the presence of the amino radicle antagonised the paralytic action of the drug.

No fatalities attributed to the use of hedonal as a narcotic have been recorded.⁹

Preparation of the Solution.

Hedonal is dissolved in normal saline at a temperature of 70° F. to make a 0.75 per cent. solution; the resultant fluid is filtered once, boiled for five minutes, and stored in sterile flasks.

Technique of Induction.

The contents of a flask are warmed up to about 140° F.,

FIG. 1.

Apparatus for continuous infusion of hedonal.

and poured into the tank, which is furnished with a thermometer, gauge, and tapped exit tube. From the latter runs a

yard of pressure tubing; in the course of this a dropper is inserted; it terminates in an ordinary fine infusion cannula. The whole apparatus has been made for me by the Holborn Instrument Company (see Fig. 1). Before infusing, the temperature of the fluid in the tank is reduced to about 115°F., if necessary, by pouring in cold solution; for long operations the tank may be placed in a felt jacket, but usually the fall in temperature of the solution is not great enough to be of importance. A good-sized superficial vein is then exposed after the injection of $\frac{1}{2}$ per cent. novocaine into the skin; into this the cannula is tied as for an ordinary venous infusion. The fluid is then run in at a rate of 50–150 c.c. to the minute; the rapidity of flow can be accurately controlled by regulating the tap and watching the flow through the dropper. In the first 50 cases the median basilic or cephalic veins were selected for infusion; under these circumstances the arm chosen must be fixed, either to a bracket of the operation table or to a separate stand; latterly we have usually injected the internal saphenous vein where it passes over the internal malleolus; this procedure has the advantage that the leg requires no special fixation, the resulting scar is out of sight, and the anæsthetist and his apparatus are well out of the way of the surgeon for most operations.

Phenomena of Anæsthesia.

A minute or so after the commencement of the infusion the patient becomes drowsy, he often yawns, he has a subjective feeling of warmth and well-being, the face flushes, and if the infusion is too rapid a certain degree of cyanosis may arise. Then follows a period in which the patient appears to be in a state of deep natural sleep; this stage merges rapidly into one of complete general anæsthesia, the deep reflexes are absent, and the corneal reflex absent or sluggish; the pupil usually contracts; the muscles, including those of the jaw, become slack. In none of the cases has there been any struggling, a few have shown slight movements of the extremities, and some talk incoherently during induction. The respiration remains quiet and regular unless it is obstructed by the falling back of the tongue, an emergency which must be guarded against; the pulse remains full and steady, the blood pressure drops slightly, and then remains fairly constant (see Fig. 2).

Course of Anæsthesia.

The amount of fluid necessary to induce anæsthesia varies considerably, 40 c.c. having sufficed in a child of 10 months; 1000 c.c. were necessary in a heavily built man of 25; the average dose required for an adult is 500 c.c. The period of induction has varied from 2 to 13 minutes.

As soon as anæsthesia is established the rate of flow of the fluid is cut down to a slow drip; the necessary rate varies with the type of patient, and is soon gauged by experience. Whenever the reflexes show signs of returning the rate of flow is again temporarily increased. The largest total amount of solution used in this series was 1750 c.c. given to Case 31, a man aged 61, anæsthesia lasting over an hour. The greatest duration of anæsthesia was 1 hour and 35 minutes in Case 60, a woman aged 36, 1125 c.c. of solution being used. It is noticeable that old people require less of the drug than do younger ones of similar body weight.

Post-operative Course.

The rate of return to complete consciousness is slow though variable; usually the patient sleeps for 6 to 12 hours after the cessation of the anæsthetic, and then awakes; drowsiness may persist for 24 hours. In three cases there has been some emotional disturbance at this stage. In some instances (17 in this series) a period of excitement comes on an hour or so after the operation; the patient, however, soon settles off to sleep if morphia is given in the usual dosage; when consciousness completely returns there is no memory of this stage. Vomiting is exceptional unless there is some irritative cause for it; it occurred in 12 cases, but in no

FIG. 2.—Blood-pressure Tracings.

DESCRIPTION OF FIG. 2.—The blood-pressure was taken at five- or ten-minute intervals during the operation by means of a Riva-Rocci apparatus applied to the arm. The horizontal lines represent the blood-pressure in millimetres of mercury; the vertical lines represent the time in minutes, the space between two adjacent lines representing five minutes. At the top of each chart is placed the quantity of fluid infused in cubic centimetres up to that point in the operation; the last number marks the time of the cessation of the infusion and approximately of the operation. The charts are so arranged that the point when the infusion was commenced is in each case placed in the same vertical line.

TABLE showing Details of 75 Cases of General Anæsthesia obtained by Continuous Infusion of Hedonal dissolved in Normal Saline Solution. The cases are arranged in chronological order. An asterisk beside the number of the case denotes that the infusion was made into the internal saphenous vein; in the other cases the median basilic or cephalic vein was selected.

Case.	Age.	Sex.	Operation.	Strength of solution.	Induction.		Subsequent progress of infusion.		Duration of operation.	Total quantity.	After-effects.		Remarks.
					Duration.	Quantity required.	Duration.	Quantity.			Headache.	Vomiting.	
1	48	M.	Passing sounds.	0.75	min. 6	c.c. 500	min. 4	c.c. 200	min. 5	c.c. 700	None.	None.	—
2	38	F.	Curetting tuberculous metacarpal bone.	0.75	5	350	8	200	8	550	Very slight.	"	—
3	36	F.	For inguinal hernia.	0.75	10	600	10	250	15	850	Moderate.	"	Patient complained of headache 4 hours after operation, but 10 hours later had no memory of previous complaint.
4	43	F.	Amputation of thigh.	0.75	5	400	20	250	25	650	None.	"	Amputation performed through lower third of thigh for compound fracture of tibia and fibula. Severe toxic symptoms.
5	47	M.	Curetting ethmoid cells. Removal of polypi.	0.75	3	300	13	510	36	810	Slight.	Once, blood swallowed during operation.	Well-marked coughing reflex maintained, especially towards the end. Patient became restless about 8 hours after operation, and had injection of morphine.
6	13	F.	For deflected nasal septum (sub-mucous resection).	0.75	4	350	17	450	21	800	"	Once, blood swallowed during operation.	Patient complained of slight headache during night after operation, but remembered nothing about it the following morning.
7	31	M.	Incisions for Ludwig's angina.	0.75	9	450	3	300	8	750	None.	None.	Onset of cellulitis very acute; moderate in degree only.
8	48	M.	Passing sounds.	0.75	5	550	11	500	11	1050	"	"	Same patient as Case 1.
9	45	F.	Maxillary antrotomy.	0.75	13	(2760)	22	650	28	(21410)	Moderate	Once, blood swallowed during operation.	Infusion apparatus leaked during induction.
10	25	M.	For adenitis of groin.	1.0	3	350	4	150	4	500	None.	None.	—
11	14	M.	For tuberculous adenitis of neck.	1.0	3	350	16	520	21	870	"	"	Slight cyanosis after induction. Rather deep narcosis.
12	60	M.	Suprapubic cystotomy; passing sounds, followed by removal of polypi.	1.0	5	450	23	650	55	1100	"	"	Duration of cystotomy was 23 mins.; the remaining 32 mins. were occupied in removing polypi.
13	33	M.	For hæmorrhoids.	1.0	5	600	12	500	12	1100	"	"	Patient was restless 12 hours after operation, but he was controlled by an injection of morphine. He was very emotional on the day following operation.
14	40	F.	Amputation of breast.	1.0	5	300	19	300	24	600	"	"	—
15	25	M.	For hernia and hydrocele.	1.0	2	400	18	620	20	1020	Very slight.	"	—
16	34	M.	Passing sounds.	1.0	3½	250	3	150	6	400	"	"	—
17	64	M.	Cystoscopy and prostatectomy.	1.0	3	200	34	500	37	700	None.	"	Good muscular relaxation.
18	21	M.	For hernia.	1.0	7	450	16	550	16	1000	Very slight.	Once 17 hours after operation.	Patient was rather restless during night after operation. Temporary block in cannula during induction.
19	63	F.	Amputation of leg at site of election.	0.75	11	550	13	200	22	750	None.	None.	Amputation performed for compound fracture of tibia and fibula.
20	40	F.	For ruptured ectopic gestation.	0.75	6	250	30	1150	37	1400	"	"	Before operation patient was extremely blanched. Pulse could just be felt at the wrist. When patient was put back to bed after operation pulse was of fair volume.
21	73	F.	Amputation of thigh.	0.75	7	320	7	180	13	500	"	"	Circular amputation for senile gangrene of foot. Death one month later with gangrene of other leg.
22	17	F.	Transpleural exploration for subphrenic abscess on left side.	0.75	7	400	15	400	24	800	"	"	Patient's condition poor. She was recovering from general peritonitis, secondary to appendicitis.
23	30	M.	Appendicectomy (perforative appendicitis).	0.75	11	750	43	1000	49	1750	"	"	Patient was suffering from compensated mitral disease. Complete muscular relaxation was obtained.
24	34	F.	For strangulated ventral hernia.	0.75	4	350	24	850	31	1200	"	"	—
25	22	M.	Appendicectomy (spreading peritonitis).	0.75	7	550	20	400	24	950	"	"	—
26	71	M.	Amputation of thigh.	0.75	5	450	9	200	14	650	"	"	Amputation was performed through lower third of thigh for gangrene. Urine contained albumin, sugar, acetone, and diacetic acid. Before operation pulse was 82, after 72. He slept during the night of operation and was quite conscious the following morning. He became drowsy during the evening and died comatose 32 hours after operation.
27	29	F.	Cholecystostomy for suppurating hydatid cysts in gall-bladder.	0.75	8	450	35	700	42	1150	"	"	Complete muscular relaxation enabling the necessary manipulations to be performed with great ease.
28	50	M.	For hernia.	0.75	8	400	15	250	18	650	"	"	Patient was emotional 6 hours after operation, alternately weeping and singing.

Continuation of Table of 75 Cases of General Anæsthesia by Intravenous Infusion of Hedonal.

Case.	Age.	Sex.	Operation.	Strength of solution.	Induction.		Subsequent progress of infusion.		Duration of operation.	Total quantity.	After-effects.		Remarks.
					Duration.	Quantity required.	Duration.	Quantity.			Headache.	Vomiting.	
29	54	M.	Excision of recurrent malignant glands of neck.	0.75	min. 5	c.c. 400	min. 37	c.c. 1600	39	2000	None.	None.	Slight restlessness 10 hours after operation. This patient had had chloroform on a previous occasion; he stated that he much preferred the intravenous method because induction was much more pleasant, there was no vomiting, and he felt much better after coming round.
30	41	M.	Passing sounds and for hernia.	0.75	4	350	15	600	17	950	"	"	Patient was slightly excited 5 hours after operation.
31	61	M.	Hemilaryngectomy.	0.75	7	550	46	1200	1 hr. 3 m.	1750	"	"	A preliminary tracheotomy was performed and a Hahn's tube inserted. The operation was carried out with great comfort; there was no coughing, and owing to the quiet respirations the larynx remained motionless.
32	21	M.	For hæmorrhage after gastro-enterostomy.	0.75	5	200	22	80	min. 32	280	"	"	Patient was taken up to the theatre 4 hours after the first operation. Pulse was 146 per minute, irregular, and very feeble. Pulse improved considerably during operation, but an hour later became more rapid and feeble. On the following morning patient's condition was much improved, and he finally made a good recovery.
33	22	F.	Resection of rib for subdiaphragmatic abscess.	0.75	2	200	7	60	8	260	"	"	Operation was performed for empyema following a partial gastrectomy for extensive carcinoma of stomach. There was severe dyspnoea, patient being unable to remain recumbent.
34	40	F.	For ventral hernia.	0.75	6	650	1 hr. 1 m.	890	1 hr. 12 m.	1540	"	"	Complete muscular relaxation; abdomen almost motionless. Developed post-operative mania on seventh day.
35	54	M.	For strangulated hernia.	0.75	6	700	min. 41	770	min. 44	1470	"	"	—
36	58	F.	Excision of tongue and glands for carcinoma.	0.75	5	48	45	400	45	880	"	"	—
37	18	F.	Adenoma of thyroid.	0.75	10	600	26	550	28	1150	"	3 times.	Patient vomited 9 hours after operation, but she only remembered vomiting once.
38	18	F.	For hernia.	0.75	6	630	13	250	15	880	"	None.	Patient was somewhat restless during night following operation.
39	62	M.	Prostatectomy.	0.75	3	300	12	225	18	525	"	For 2 days commencing 48 hours after operation. 3 times.	The vomiting was considered uræmic since the quantity of urine in 24 hours was much diminished, and patient recovered after treatment by hot baths, &c.
40	42	F.	Ileo-sigmoidostomy.	0.75	5	500	1 hr. 1 m. min. 3	680	1 hr. 10 m. min. 9	1180	"	None.	Patient was stout. Abdomen was flaccid throughout operation.
41	57	M.	Amputation of toe.	0.75	4	400	36	810	43	500	"	None.	Complete return of consciousness 1 hour after operation.
42	49	M.	Syme's amputation.	0.75	5	300	24	700	24	1110	Slight.	"	Tumour removed through bronchoscope.
43	62	M.	Excision of fibroma from aryteno-epiglottic fold.	0.75	4	350	16	400	20	820	Moderate.	None.	—
44	50	F.	For double femoral hernia.	0.75	4	420	12	500	16	920	None.	"	—
45	34	M.	For hernia.	0.75	7	1000	16	200	20	1250	"	"	This patient had had a previous anæsthetic for a varicocele 10 years ago; he stated that he much preferred the intravenous method.
46	27	M.	"	0.75	7	1000	16	200	20	1250	"	"	On return of consciousness patient had no memory of vomiting.
47	15	F.	Appendicectomy.	0.75	4	300	24	780	28	1080	"	Once; 9 hours after operation.	This patient had been given chloroform a few days before; when asked, he said he preferred the intravenous method.
48	14½	M.	Amputation of leg at site of election.	0.75	3	250	33	330	35	580	"	None.	—
49	62	F.	Excision of malignant glands of axilla.	0.75	4	350	29	450	35	800	"	"	—
50*	66	F.	For inguinal hernia.	0.75	4	500	25	350	31	850	"	"	Slight cyanosis during induction. Erythematous rash appeared on body 12 hours after operation. Slight itching.
51*	46	M.	Excision of inferior maxilla and portion of cheek on left side for carcinoma.	0.75	6	600	1 hr. 29 m.	580	1 hr. 34 m.	1180	"	"	—
52*	10 ms	M.	For hernia.	0.75	8	40	min. 10	60	min. 11	100	Not apparent.	"	Abdomen completely relaxed. Patient's colour was very good throughout.
53*	59 yrs.	M.	For epithelioma of floor of mouth.	0.75	7	600	55	650	1 hr.	1250	None.	"	—
54*	50	F.	For ventral hernia.	0.75	8	700	1 hr. 5 m.	625	1 hr. 7 m.	1325	Slight.	"	Cyanosis. Patient suffered from varicose veins. This might account for the somewhat large quantity required for induction. The patient remained sleeping for 10 hours after the operation.

Continuation of Table of 75 Cases of General Anæsthesia by Intravenous Infusion of Hedonal.

Case.	Age.	Sex.	Operation.	Strength of solution.	Induction.		Subsequent progress of infusion.		Duration of operation.	Total quantity.	After-effects.		Remarks.
					Duration.	Quantity required.	Duration.	Quantity.			Headache.	Vomiting.	
55*	66	M.	Excision of carcinomatous ulcer of cheek and glands.	0.75	min. 6	c.c. 625	1 hr. 22 m.	c.c. 575	1 hr. 27 m.	c.c. 1200	None.	None.	Slight bronchitis; cough present before operation. Moderate cyanosis was present during early part of operation; probably rather deep narcosis.
56*	25	M.	For caries of sternum.	0.75	4	250	min. 7	105	min. 9	350	"	"	This patient had signs of old phthisis. He suffered from cough before operation. Cough was worse for 12 hours after operation. Large quantity of frothy mucus expectorated.
57*	35	F.	Excision of adenoma of thyroid.	0.75	9	700	20	450	24	1150	"	"	This patient had slight exophthalmos. Pulse 90. She was emotional during induction. A marked feature was the absence of engorgement of veins during operation. Patient apparently suffered no shock from the operation.
58	37	M.	Amputation of thigh for senile gangrene of leg.	0.75	6	300	16	200	21	500	"	"	On the morning after operation patient had no memory of vomiting.
59	38	M.	Suturing cut thigh.	0.75	8	520	30	760	30	1280	"	Once, 7 hours after operation.	
60*	36	F.	Uretero-cæcostomy.	0.75	5	300	1 hr. 30 m.	825	1 hr. 35 m.	1125	"	Once.	Operation performed for extensive papilloma of bladder. Complete muscular relaxation. On morning after operation, patient had no memory of vomiting.
61*	40	M.	For hernia.	0.75	12	675	min. 36	275	min. 41	950	Slight. None.	None.	—
62*	15	F.	Appendectomy (spreading peritonitis).	0.75	11	550	20	400	24	950			
63*	45	F.	Excision of recurrent malignant glands of axilla.	0.75	8	740	54	475	54	1215	Moderate	Once, 9 hours after operation.	Patient had been given ether for two previous operations. She stated that she much preferred the intravenous method. No recollection of vomiting. Restlessness 12 hours after operation controlled by morphine.
64*	23	M.	Excision of axillary glands.	0.75	10	700	1 hr. 10 m.	520	1 hr. 10 m.	1220	None.	None.	—
65*	65	F.	For acute obstruction and general peritonitis due to carcinoma of rectum	0.75	7	150	min. 18	310	min. 19	460	"	"	Patient's condition was very bad before operation. She improved somewhat afterwards. Consciousness returned 4 hours after operation. Patient died 12 hours later.
66*	4	M.	Colostomy for idiopathic dilatation of colon.	0.75	8	300	23	175	37	475	"	"	Cyanosis shortly after operation was commenced; abolished by drawing forwards tongue and giving oxygen. Patient was given hypodermic injection of scopolamine gr. 1/100, atrop. sulph. gr. 1/120, morph. gr. 1/6 half an hour before operation. History of stridor. At operation trachea found to be scabbard-shaped, and during delivery of tumour trachea was kinked, causing respiratory obstruction, which was at once relieved by removal of tumour. Oxygen given. Recovery uninterrupted.
67*	23	F.	Excision of adenoma of thyroid.	0.75	5	400	35	300	35	700	"	"	
68*	26	F.	Nephrectomy for tuberculous kidney.	0.75	5	400	55	400	52	800	"	"	Previous hypodermic injection of scopolamine gr. 1/100, atrop. sulph. gr. 1/120, morph. gr. 1/6. At the close of operation cannula became blocked owing to coagulation of blood which had regurgitated, this being caused by temporary lowering of cannula. Some cyanosis was present during the early part of operation. Three-quarters of an hour before operation patient was given 4 grm. of hedonal by mouth. He was semi-comatose at commencement of operation; no local anæsthetic was required for exposure of vein. Complete return of consciousness 15 hours after operation.
69*	68	F.	For umbilical hernia.	0.75	5	250	25	200	35	450	Slight.	Once, 9 hours after operation.	
70*	36	M.	Radical cure of double inguinal hernia.	0.75	6	250	45	390	45	640	"	None.	Hedonal before operation as in Case 70. Consciousness completely returned 12 hours after operation ended.
71	24	M.	For varicose veins.	0.75	9	475	35	750	44	1225	None.	"	Hedonal was given by the mouth as in Case 70. Return of consciousness 12 hours after operation.
72	46	M.	For hæmorrhoids.	0.75	10	450	7	100	10	550	"	Once.	—
73	29	F.	For varicose veins.	0.75	8	700	24	550	25	1250	Slight.	None.	—
74*	21	M.	For perforated duodenal ulcer.	0.75	11	710	37	700	47	1410	None.	"	—
75*	38	F.	Exploration of cerebral tumour.	0.75	5	300	25	500	35	800	"	Once.	—

instance was it persistent. Headache of slight degree and lasting part of a day was complained of in 15 cases. The urine showed no change in any of the cases in which it was tested for the common abnormalities. Dr. H. B. Weir examined the blood before, during, and after anæsthesia in six cases and did not find any evidence of hæmolytic. In no case has there been any evidence of local thrombosis in the veins; among the later cases thrombosis has been observed in 3 patients.

Dangers of Hedonal Anæsthesia.

Cyanosis is the only symptom in this series which has given cause for alarm. A certain degree is common during the initial stage of anæsthesia and passes off if the rate of flow of the fluid is diminished. It has appeared during the course of the operation in six instances (Cases 11, 12, 54, 55, 67, and 69), and in all except Case 54 it was caused by obstruction of the air passages—either from the falling back of the tongue and jaw or from pressure on the trachea; in Case 54 a large dose of fluid had been infused unusually rapidly, and the respiratory movements became slow and shallow, the normal rhythm returning a few minutes after the inflow had been cut down. Federoff⁶ reports that temporary stoppage of respiration occurred in 8 out of 530 cases, in each instance normal breathing setting in again after a few movements of artificial respiration.

Disadvantages of the Method.

The exposure of an adequate vein sometimes gives difficulty. If the novocaine injection is properly made the procedure is painless. In children the vein is necessarily small, but in Cases 52 and 66 the internal saphenous vein where it lay over the internal malleolus proved to be of sufficient size. Induction of anæsthesia may be slow if the fluid does not flow freely. Such a state of affairs may be due to the use of too small a cannula, to partial block in the tubing, or to the selection of a vein of exceptionally narrow calibre. In one or two instances where infusion was carried out in the leg slow induction has seemed to be associated with a varicose condition of the veins, the fluid percolating all the vessels of the lower extremity, and, as it were, remaining for a time in a backwater of the general circulation.

The prolongation of narcosis after the operation may be undesirable in trivial cases; it might prove dangerous from the inhalation of vomitus in cases of unrelieved intestinal obstruction.

Advantages.

The technique is simple, the solution readily handled and sterilised, and the active part is not volatile. The anæsthesia attained is of a steady and complete type; the relaxation of the muscles is remarkable, being often as good as that given by spinal anæsthesia. The respiratory movements are steady and quiet. The removal of the anæsthetist from the scene of the operation in head and neck cases is a distinct advantage. In cases of hæmorrhage or collapse the combination of the anæsthetic with infusion is very valuable; this was particularly noticeable in Cases 20, 22, 27, 32, and 33. The absence of any inflammatory complication of the lungs has been a noticeable feature in this series; in only three instances (Cases 55, 56, and 70) have any been observed. The quiet sleep, insensitiveness to pain, and absence of straining—conditions which usually last from six to eight hours after operation—are certainly very desirable in many cases.

Owing to the comparatively slow rate at which the drug is excreted very small quantities of solution suffice to maintain anæsthesia, when once it has been completely established; thus in Cases 51 and 60 the operation lasted over an hour and a half, the total amounts of fluid infused being 1180 c.c. and 1125 c.c. respectively.

In operations on the thyroid and larynx (Cases 31, 35, 57, and 67) the quiet even anæsthesia is very satisfactory. In all cases the patients experience pleasant sensations throughout the induction period, and they seldom complain of any evil after-result.

Contra-indications to the Method.

In conditions where there is marked engorgement of the lungs, or when the cardiac action is not properly compensated, infusion anæsthesia is likely to put a dangerous strain on the right side of the heart. In cases of nephritis it might be expected that the kidneys could not adequately deal with the infused solution, but in Cases 12, 17, and 39, in which

there was evidence of chronic nephritis, no ill-result ensued. In Case 68 the right kidney was excised from a patient suffering from general tuberculosis of the urinary system; there were no uræmic signs at any time, and she has made a good recovery. It is noticeable that the amount of fluid necessary to produce anæsthesia in these cases was not very large. Arterio-sclerosis and conditions in which the blood pressure is high do not seem to be absolute contra-indications to the use of the method.

From the limited experience of this series of cases I have been led to conclude that the method is a safe and sure one in patients up to middle age, providing that there is no gross pulmonary or cardiac lesion; in the aged or in cases where there is myocarditis or marked arterio-sclerosis great care in the administration is required, as the safe margin allowable for overdosage is undoubtedly narrower.

A few attempts were made to reduce the necessary amount of fluid infused by administering other drugs before the induction. In Cases 67 and 69 an injection of scopolamine gr. 1/100, morphine sulphate gr. 1/6, and atropine sulphate gr. 1/120 was given half an hour before operation; in Cases 70, 71, and 72 4 grammes of hedonal were given in an emulsion about three-quarters of an hour before operation, and followed by a hot drink of some kind. In the first two cases the amount of solution necessary to produce anæsthesia was rather less than might have been expected, but in both instances more cyanosis than usual was developed during anæsthesia; in Case 67, in which a thyroid adenoma was enucleated, this was chiefly due to mechanical pressure on the trachea. Of the latter three cases 70 and 72 were partly narcotised before the commencement of the infusion, and required much less than usual of the solution. Case 71 was in a state closely resembling the excitation stage of ether anæsthesia, but required a considerable dose to induce complete narcosis. All three slept heavily after the operation and seemed somnolent and somewhat depressed during the following day. I think that for strong, healthy patients a dose of 3 grm. of hedonal given about two hours before the operation would give better results.

Analysis of Cases which Terminated Fatally.

In this series no death has occurred which could be attributed to the anæsthetic. Five died at some period subsequent to the operation while still in hospital. An account of the course of these cases follows:—

CASE 19.—The patient was a female, aged 60, with compound comminuted fracture of the leg. Amputation below the knee. The wound healed well, and the patient appeared to be in a state of good general health till three weeks after the operation, when she died suddenly with the signs of pulmonary embolism. Post mortem a large ante-mortem clot was found in the pulmonary artery; there was no evidence of local thrombosis in the vein (median basilic), which was used for the infusion.

CASE 21.—The patient was a female, aged 73, suffering from senile gangrene of the feet. Amputation through the thigh. Death ensued one month later from spreading gangrene of the remaining leg.

CASE 26.—The patient was a male, aged 71, suffering from diabetic gangrene of the foot. Amputation through the thigh. The patient was in a drowsy state before operation, and died in coma 32 hours afterwards. The urine contained much sugar, diacetic acid, and a fair quantity of albumin before the operation.

CASE 27.—The patient was a female, aged 24, with a suppurating hydatid cyst of the liver; cholecystostomy; death one month later. Post mortem there were found suppurative cholangitis, suppurating cyst of the liver, empyema, and general peritonitis.

CASE 65.—The patient was a female, aged 65, with carcinoma of the rectum. Laparotomy for acute intestinal obstruction. At the operation general peritonitis was found following a perforation in the large bowel. The patient was in a state of extreme collapse before the operation; she improved after the infusion, but sank again afterwards, and died seven hours later.

Since writing the above a death from syncope has occurred in a feeble old man half an hour after the administration of hedonal. A gastrostomy had been performed; signs of heart failure set in directly after the administration of a feed. Post mortem a carcinoma of the œsophagus opposite the bifurcation of the trachea was found, from which an abscess

had spread into the mediastinum. The aortic valves were grossly diseased and incompetent.

Summary.

1. The intravenous infusion of a 0.75 per cent. solution of hedonal in normal saline solution produces general anaesthesia.
2. Administration of the solution by continuous infusion gives good results.
3. The anaesthesia is steady and complete; is associated with great relaxation of the muscles, and has a wide margin of safety.
4. During anaesthesia the respiration remains steady and the pulse good; the blood pressure usually falls slightly.
5. The induction of anaesthesia is subjectively very pleasant to the patient; little if any excitement occurs during this stage.
6. Anaesthesia is established in from 5 to 10 minutes; the rate of inflow of the fluid should be from 50 to 150 c.c. to the minute; a slower rate greatly delays the induction of anaesthesia; a more rapid one may produce signs of cyanosis.
7. The comparatively slow rate at which the drug is excreted make it possible to maintain anaesthesia for prolonged periods without infusing a very large volume of fluid.
8. The anaesthetic stage usually merges into one of deep sleep, which lasts from 6 to 12 hours.
9. Vomiting or headache at the post-operative period is uncommon.
10. Pulmonary complications are rare.
11. The dangers which may arise during anaesthesia are respiratory depression from an overdose of the drug and respiratory obstruction from falling back of the tongue and jaw.
12. The method is very suitable for operations about the head and neck; the muscular relaxation and quietness of the respiratory movements also make it a valuable anaesthetic for operations in the upper part of the abdomen.

In conclusion, I wish to acknowledge the courtesy of the members of the surgical staff of St. Thomas's Hospital in permitting me to make use of the cases admitted under their care. I am indebted to several of my colleagues for much assistance in carrying out these observations, more especially to Mr. B. O. Maybury, surgical registrar, who has done a great deal of work in the matter and has prepared the tables giving details of the cases and the blood pressure records.

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St. Thomas's Hospital, S.E.

VICIOUS CIRCLES ASSOCIATED WITH DISORDERS OF THE NOSE, THROAT, AND EAR.

By JAMIESON B. HURRY, M.A., M.D. CANTAB.,
LATE MEDICAL OFFICER, UNIVERSITY COLLEGE, READING.

THE importance of the morbid process known as the vicious circle has of recent years come to be widely recognised. There are few ailments that do not in some measure come within the orbit of its perturbing influence, and the practitioner will reap a rich reward who is ever on the look-out for this complication, and who bases his treatment on a full recognition of the ceaselessly acting and reacting forces that constitute the circle. In the following article attention is drawn to an interesting group of circles associated with the nose, throat, and ear. Some of these are important because very common; others because of their frequently fatal issue.

I. The Nose.

Diseases of the nose are frequently complicated by the operation of a circle, which largely accounts for the rebellious nature of many disorders. Stenosis and abnormal patency play a leading part in the genesis of such a complication and will be dealt with first.

Stenosis.—In regard to stenosis some of the reciprocal relations may be thus stated: "Obstruction, by preventing or interfering with the expulsive force of the expiratory current, prevents the removal of the usually abnormal amount of secretion, either by blowing the nose or otherwise; its accumulation is in its turn an efficient factor in producing obstruction, and a vicious circle is thus established."¹ Inflammatory and hypertrophic affections of the nasal mucosa also react on one another where stenosis is present; for the secretions, being unduly retained, are then specially apt to undergo putrefaction and keep up irritation. Post-nasal growths, such as adenoids, likewise tend to increase as a result of a circle, at any rate so long as nasal respiration continues. For every act of inspiration lessens the barometric pressure behind the obstruction, and thus leads to hyperæmia and hypertrophy. Especially is such hypertrophy brought about in children whose lymphoid tissue so readily responds to stimulation.² Hypertrophic rhinitis is another frequent result of chronic stenosis, acting by the barometric rarefaction associated with inspiration that has just been alluded to.

Watson Williams³ has pointed out that deflection of the septum and nasal obstruction react on each other. The deflection causes stenosis on the side of the convexity, leading to diminished pressure behind the obstruction, which diminution tends to aggravate the deflection. A somewhat similar "vicious circle of events," in the words of Risley,⁴ occurs when, owing to deformities of the scroll bones of the nostrils and to deviations of the septum or vomer, the nasal chamber is so narrowed that the opposing sides come into contact or approach so nearly that any congestion of the lining mucosa brings them together. Here, too, a self-aggravating factor comes into play, since the opposing pressures impede the congestion. Congestion breeds congestion. The nose becomes stopped by the turgid soft tissues and drainage is checked.

Mouth-breathing introduces a further aggravating factor⁵; "a vicious circle is set up. Mouth-breathing tends to obstruct the nose, and this very obstruction maintains and continues the mouth-breathing."⁶ The tendency to adenoids is also increased by mouth-breathing. Oral respiration, when begun in early life and associated with malnutrition and debility, is of some sociological interest. For the partial abeyance of the respiratory function has far-reaching effects, and perpetuates a condition of impaired vitality, and the victim muddles through life at a low level of health. Especially is this result probable when mouth-breathing is established in infancy. The nasal passages are then so narrow that even slight engorgement leads to complete closure. Another circle associated with stenosis is collapse of the alæ nasi. The nostrils collapse instead of expanding on inspiration, and may thus convert the anterior nares into mere slits. In severe cases the alæ may actually fall against the septum.

Abnormal patency.—Abnormal patency of the nasal fossæ due to an enlarged interval between the spongy bones and the septum has much to do with the circle that complicates atrophic rhinitis or ozæna. For as the velocity of a stream grows less with a wider channel so does the air passing through the enlarged nasal passages lose the velocity and force required to expel the tenacious nasal secretions. Hence result stagnation, putrefaction, foetor. In course of time the inspissated secretions contract like a film of collodion, leading to anæmia and atrophy of the mucosa, to shrinking of the turbinates, and to yet greater patency of the meatuses. Thus the morbid condition is perpetuated. Greville MacDonald has observed a similar sequence after the removal of a polypus.

Sinusitis.—Reciprocal relations are frequently established in connexion with sinusitis. Owing to the narrowness of the ducts draining the sinuses congestion readily leads to partial obstruction followed by retention and putrefaction of the secretions. The consequent irritation provokes further swelling and finally complete obstruction. In some cases—

¹ Ashhurst: Cyclopaedia of Surgery, vol. v., p. 404.

² Greville MacDonald: Diseases of the Nose, p. 20.

³ Diseases of the Upper Respiratory Tract, p. 337.

⁴ Brit. Med. Jour., 1906, vol. ii., p. 1869.

⁵ Stoerk long ago pointed out that the nasal mucosa can only remain healthy and carry out its functions so long as it is exposed to the respiratory currents of air. When deprived of these it may undergo all degrees of disorder from catarrh to total destruction. Cf. Erkrankungen der Nase, des Rachens, und des Kehlkopfes (Nothnagel's Pathologie und Therapie), p. 34.

⁶ Mayo Collier, Mouth-breathing, p. 12.