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Chronic Hemodialysis for Terminal Renal Failure

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ABSTRACT

Ten terminal uremic patients seen over the period of one and one-half years have been kept alive by repeated hemodialysis using a modification of the Seattle system, carried out for the most part by nurses and technicians. All the patients had creatinine clearance values below 5 ml./min., and blood urea nitrogen values which ranged between 156 and 453 mg. % before beginning the first dialysis.

Selection was based on their ability to co-operate with and to tolerate the regimen. Nine patients were fully rehabilitated.

The major complications were those related to shunt-site infections, including septicemia, bacterial endocarditis, septic arthritis, septic pulmonary embolism and mycotic aneurysm.

Nevertheless, all patients except one were rehabilitated and resumed their full-time occupations and have continued to lead happy and useful lives.

SOMMAIRE

Au cours d'une période d'un an et demi, on a maintenu en vie 10 urémiques en phase terminale, au moyen d'hémodialyses répétées par le système de Seattle modifié et exécutées en général par des infirmières et des techniciens. Chez tous les malades, la "clearance" de la créatinine était inférieure à 5 ml./min.; les chiffres de l'azote uréique variaient de 156 à 453 mg. %, avant le début de la première dialyse.

Ces malades ont été choisis pour leur capacité de collaborer et de tolérer le traitement. Neuf malades ont été entièrement réhabilités.

Les principales complications qui sont survenues étaient relatives aux infections du siège de la dissection artério-veineuse, parmi lesquelles figuraient septicémie, endocardite bactérienne, arthrite infectieuse, embolie pulmonaire septique et anévrisme d'origine fongique.

Néanmoins, tous les malades, sauf un, ont pu être réhabilités et reprendre leurs occupations normales. Ils ont depuis continué à mener une vie heureuse et utile.

SINCE the advent of periodic hemodialysis as a technique for sustaining life of terminal uremic patients, first described in 1960 by Scribner *et al.*¹ in Seattle, Washington, a number of centres have been using similar methods. The chronic dialysis unit at the Montreal General Hospital has been in operation for the past one and one-half years, employing essentially the same principles as those in use in Seattle. This communication describes our experience in prolongation of life of patients with terminal renal insufficiency on repeated dialysis.

ORGANIZATION

The chronic dialysis unit is made up of two rooms, one 24 feet x 25 feet in size, for preparation of the artificial kidneys, and the other, the dialyzing room, 21 feet x 22 feet, located on one of the medical wards.

The unit is staffed by the authors, who supervise the medical aspects of the dialysis program, which consumes about 25% of their time, with the nurses and the technicians performing the actual operations of the unit. Two technicians prepare the kidneys, make the shunts and deal with the technical

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problems that emerge; as well, these technicians are familiar with the nursing aspects of the program. The seven nurses on the unit staff do the actual dialyzing, placing the patients on and taking them off the kidneys, and monitoring the course of the dialysis; these nurses are also familiar with the major technical aspects of the program. Thus, when a leakage or clotting of the kidneys develops, the nurses can assemble a new kidney without the assistance of the technicians.

METHOD

The equipment used is a modification of that used in Seattle and has been described by Kaye and Posen.² Modified Kiil kidneys* are used for each patient. The advantages of this type of low-resistance pumpless dialyzer are that it is associated with very little hemolysis of the red blood cells, that distortions of the blood vessels at the cannula sites are minimal, and that no blood is used for priming. These features make these units admirably suited to repeated dialysis. The dialysate fluid is supplied by a common 200-litre bath (Figs. 1 and 2). The composition of the bath fluid is as follows: glucose—2000 g., sodium bicarbonate—454 g., sodium chloride—1110 g., sodium acetate $\cdot 3 \text{ H}_2\text{O}$ —218 g., potassium chloride—44 g., calcium chloride $\cdot 2 \text{ H}_2\text{O}$ —32 g., magnesium chloride $\cdot 6 \text{ H}_2\text{O}$ —22 g., and lactic acid—68 c.c. This gives a final electrolyte concentration of sodium 130 mEq./l., bicarbonate 27 mEq./l., chlorides 101 mEq./l., potassium 3 mEq./l., magnesium 1.0 mEq./l., and calcium 2.4 mEq./l. The pH of this solution is 7.0.

*Sweden freezer.

Heparin is infused into the proximal portion of the arterial tubing by a constant infusion pump* to prevent clotting in the kidney. No protamine is used unless bleeding is occurring or is anticipated. The total amount of heparin per dialysis varies not only with the duration of a single dialysis, but also with the individual.

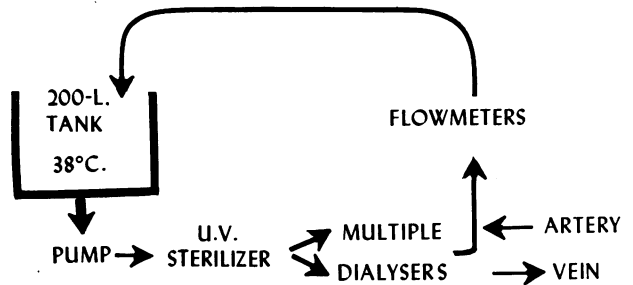


Fig. 1.—Diagram of dialysate circuit.

The chemicals are weighed beforehand and are placed in different coloured plastic bags. Each individual bag, containing a single chemical, is then weighed again and the seven bags are placed together in one large bag which then contains everything for one bath. The bath is changed every two hours.

The procedure of placing the patients on and off the dialysis has been previously described.¹ Up to five patients are dialyzed simultaneously, and between dialyses an arteriovenous Teflon shunt connects the arterial and venous cannulas in each patient.

*Harvard infusion pump.

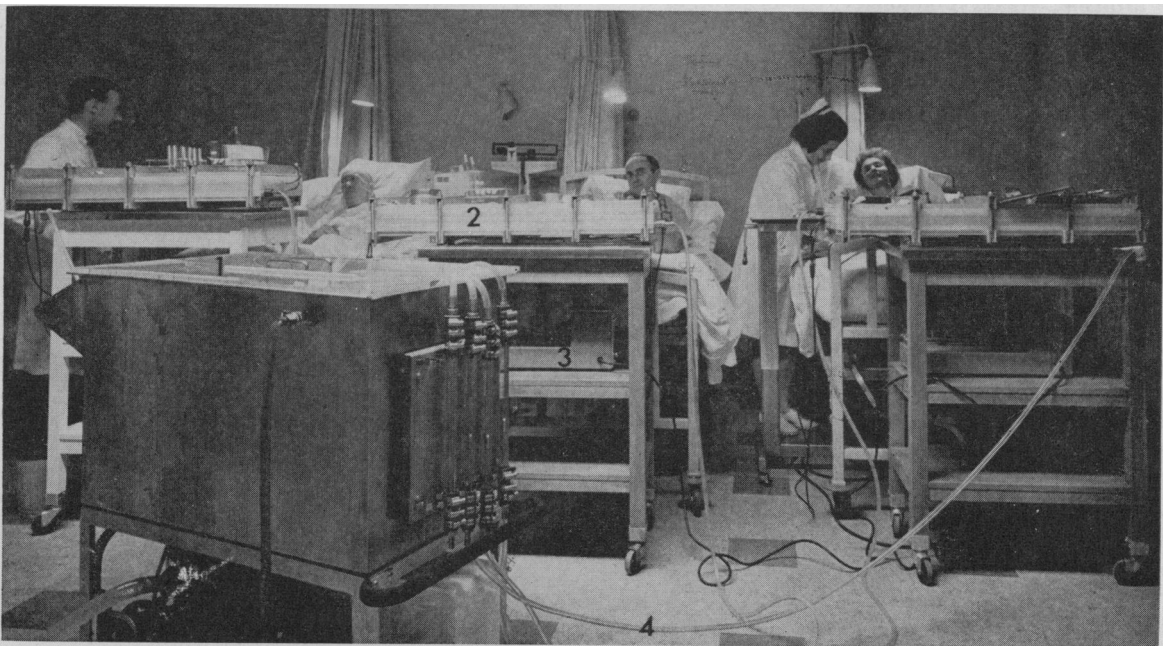


Fig. 2.—Photograph of the dialysis area which accommodates up to five patients simultaneously: 1—the 200-litre tank, 2—the Kiil dialyser, 3—the heparin infusion pump, and 4—dialysate returning to the flowmeter and thence back to the bath.

TABLE I.—CLINICAL DATA

Case	Age*	Diagnosis	Duration on program	Dialysis schedule per week	Clinical grade ^a	Daily urine output	No. of major complications	Duration in years of known renal disease
1	48	Chr. glom.	23½ mo.	12 hr. x 1	I A	375 c.c.	2	22
2	38	Chr. glom.	19 mo.	8 hr. x 2	I A	205 c.c.	3	5
3	52	Chr. glom.	17 mo.	12 hr. x 2	I A	0-250 c.c.	8	3
4	28	Chr. glom.	16 mo.	8 hr. x 2	I A	250 c.c.	4	7
5	39	Chr. glom.	15 mo.	12 hr. x 2	I A	0	4	20
6	30	Chr. glom.	14 mo.	10 hr. x 2	I A	300 c.c.	0	1
7	42	Chr. glom.	16 mo.	12 hr. x 2	I A	170 c.c.	1	4
8	48	Hered. neph.	5 mo.	12 hr. x 2	I A	300 c.c.	0	23
9	48	Hered. neph.	6 mo.	8 hr. x 2	I C	200 c.c.	2	7
10	42	Chr. glom.	2 mo.	12 hr. x 2	I A	100 c.c.	0	9

*At April, 1965.

Chr. glom.—chronic glomerulonephritis.

Her. neph.—hereditary nephritis.

PATIENTS

Ten patients are being maintained on the program at the present time. Of these, seven are men and three are women. Their ages range from 29 to 52 years, the average age being 43 years. The primary diseases which led to uremia were chronic glomerulonephritis in eight and hereditary nephritis in two. All the patients were in terminal uremia before being placed on the program, and had creatinine clearances of less than 5 c.c./min. The periods for which the patients have been on chronic dialysis range between two months and 24 months, with an average of 13.2 months. Seven of the 10 have been on dialysis for over one year. All patients except one are dialyzed twice per week, for periods ranging between eight and 12 hours per dialysis. The remaining patient is dialyzed once a week for 12 hours (Table I).

All of the male patients are clinically well and are able to work, but two are unemployed because they are unable to obtain work. Two of the three women do their usual housework; one woman who had been chronically ill and grossly debilitated prior to being placed on the program is the only patient who is unable to carry on her previous activity.

Nine patients are married, with children; the other one is a bachelor. They are on a special diet consisting of 20 mEq. of sodium, 60 mEq. of potassium and 60 g. of protein per day. They are permitted to drink fluids to satisfy their thirst and no more. They or their spouses are instructed to take their blood pressures and record them on a chart, and are shown how to clean and change their catheter dressings daily at home. They are admitted to the hospital after a day's work and are dialyzed overnight while they sleep. They return to work the next day.

Selection of the patients is based on psychiatric and medical assessment. For the former, each was interviewed by a psychiatrist and psychological testing was carried out. Preferably, the interviews were done before the mental changes of terminal uremia had occurred; in some instances they were repeated several weeks after dialysis had been

started. Great stress is placed on the ability of the patient to co-operate with and to tolerate the regimen. Although age is not decisive, those over 50 years of age are not considered likely candidates in view of the greater tendency of individuals in this age group to peripheral arterial sclerosis, which makes the insertion of arteriovenous shunts difficult. Pre-existing diseases such as diabetes, advanced pulmonary disease or arteriosclerotic heart disease are considered to be contraindications to chronic dialysis. Hypertension is not a contraindication to chronic dialysis since this can be corrected by reducing the extracellular fluid volume with dialysis.

CLINICAL PICTURE BEFORE PLACEMENT ON PROGRAM

All of the patients were in irreversible renal failure before entering the chronic dialysis program. The interval from the time that kidney disease was first discovered to the time when they were admitted to the program ranged between one and 25 years.

All presented with fatigue and hypertension for one or more years prior to onset of terminal renal failure; seven of the 10 patients had nausea and vomiting. Case 6 presented in frank pulmonary edema. This patient went on to develop supra-ventricular tachycardia and later complete atrio-ventricular dissociation with right bundle branch block. She had uremic pericarditis at that time and her serum potassium was 6.3 mEq./l. Five patients (Cases 2, 5, 7, 9 and 10) had shortness of breath on exertion, orthopnea, or both, but all had clinical or radiological evidence of pulmonary edema or congestion. In addition to Case 6, one other patient (Case 9) had a pericardial friction rub. One patient (Case 5) had a cardiac arrest when his serum potassium was 8 mEq./l. at the time of assessment. All had proteinuria and red blood cells, white blood cells and casts in the urinary sediment. All were anemic, with an average hemoglobin of 7.2 g. % and a hemoglobin range of 5.9 g. % to 8.9 g. %. None had clinical evidence of peripheral neuropathy. The fundoscopic examina-

TABLE II.—BLOOD PRESSURE, WEIGHT AND CONDITION OF THE OPTIC FUNDI INITIALLY AND AT MOST RECENT ASSESSMENT

Case	Blood pressure (mm. Hg)		Weight (lb.)		Retinopathy (Keith-Wagener grade)		Anti-hypertensive agent
	Initial	Present	Initial	Present	Initial	Present	
1	180/110	170/72	159	130	I	I	—
2	190/100	180/105	148	136	III	II	+
3	240/130	147/75	139	137	III	Arterio.	—
4	190/140	178/108	147	135	III	I	+
5	190/130	172/108	166	142	III	I	+
6	160/90	120/88	117	113	Normal	Normal	—
7	210/130	152/105	181	147	IV	Normal	—
8	175/110	160/96	165	146	III	Normal	—
9	184/104	190/98	132	105	Arterio.	Arterio.	—
10	190/140	120/88	148	145	III	I	—

tion at the time of presentation ranged from normal to Grade IV hypertensive retinopathy.³ The blood urea nitrogen levels varied between 156 and 453 mg./100 ml., with an average of 218 mg./100 ml. The initial creatinine values averaged 21.9 mg./100 ml. and ranged between 15 mg. % and 25.2 mg. %. All were acidotic, with a CO₂ combining power that varied between 8 mEq./l. and 22 mEq./l., with an average of 16 mEq./l. Four patients were hyperkalemic. Skeletal surveys in all were normal. Two patients had soft-tissue calcification at the time of their admission to the program. One of the two had an alkaline phosphatase of 50 King-Armstrong units. Her serum calcium was 8 mg. % and phosphorus 9.4 mg. %.

RESULTS OF CHRONIC DIALYSIS

During the period from January 1964 to the end of April 1965, all of the 10 patients remained alive and well. According to the criteria defined by Gombos *et al.*⁴ for evaluation of the effect of dialysis on performance, nine patients fall into Class I, Group A. One patient (Case 9) is classified as Class I, Group C. Class I, Group A is defined as those patients who are able to carry on normal activity with no complaints and no clinical evidence of disease, and Class I, Group C as those patients who are able to carry on normal activity with effort but who have clinical evidence of disease.

In all cases the patient's general well-being improved after three to four weeks on dialysis. All the patients except one are able to do a regular day's work, but two are unemployed because they are unable to obtain work. Nausea and vomiting, congestive cardiac failure and fatigue have been corrected.

Hypertension has been corrected in six patients by means of sodium restriction and initial fluid removal. This is usually accomplished by two or three peritoneal dialyses when the patient is being prepared for admission to the program. This method of dialysis has the additional advantage of removing urea gradually, thus avoiding the post-dialysis syndrome, which results from a delayed clearance of urea from the cerebrospinal fluid and the brain, creating an osmotic gradient with a shift of water into the brain and cerebrospinal fluid.⁵ Furthermore, initial peritoneal dialysis results in

removal of edema fluid from the limbs, making it easier to implant a catheter at the shunt site and to prevent postoperative infections.

Three of the patients are still maintained on an antihypertensive agent, alpha-methyldopa (Aldomet), 250 mg., from two to four times per day according to the standing blood pressure. Usually, antihypertensive agents are not necessary on the day after dialysis. Hypertensive retinopathy has improved to normal or Grade I in all except one patient who still has Grade II retinopathy (Table II).

TABLE III.—HEMATOLOGICAL DATA

Case	Hemoglobin (g. %)		Blood per month (No. of units packed cells)	Heparin per dialysis (mg.)
	Initial	Present		
1	8.6	6.9	2.0	235
2	8.5	7.5	3.3	174
3	7.9	6.2	3.3	218
4	8.1	8.0	3.0	220
5	7.2	8.1	3.6	240
6	8.7	8.0	0.8	160
7	8.9	7.5	3.3	240
8	5.9	8.0	3.6	155
9	8.7	6.7	3.3	167
10	7.5	7.1	3.0	185

All of the patients are anemic, with an average hemoglobin value of 7.2 g. % (Table III). They require from 1 to 3.6 units of blood per month to keep their hemoglobin at their average value. This is given as washed, packed red blood cells. The amount of blood given each patient is based on the pre-dialysis hematocrit values. If the hematocrit is above 23%, no blood is given; if it is between 23 and 21%, one unit of blood is given, and if it is below 21%, two units of blood are given.

Frequent, repeated hemodialyses maintain the patient's blood urea nitrogen levels below 100 mg./100 ml. in all cases; their average values ranged between 67 mg./100 ml. and 91 mg./100 ml. pre-dialysis and between 20 mg./100 ml. and 42 mg./100 ml. post-dialysis. The average creatinine plasma levels varied between 8.3 mg./100 ml. and 15.5 mg./100 ml. pre-dialysis, and between 4.6 mg./100 ml. and 7.3 mg. % post-dialysis (Table IV and Fig. 3).

stream infection. This patient on another occasion also developed a mycotic aneurysm at the arterial catheter site resulting from a local infection; this later bled excessively while he was on hemodialysis.

Hemorrhage from erosion of an artery at an infected catheter site occurred in another patient (Case 9) who has had recurrent local infections.

COMPLICATIONS NOT RELATED TO CATHETER-SITE INFECTIONS

The post-dialysis syndrome occurred on two occasions during the first few dialyses when the techniques of reducing the blood urea nitrogen gradually with peritoneal dialysis or by means of a few short initial hemodialyses were not being employed. Serum hepatitis due to blood transfusions occurred on two occasions without undue consequences. One patient had several episodes of upper gastrointestinal hemorrhage from a pre-existing duodenal ulcer while he was being dialyzed.

Heart failure occurred five times in four patients. Over-hydration with consequent hypertension was the cause in one patient. In two older individuals who were not unduly hypertensive at the time they developed congestive cardiac failure, moderate over-hydration was associated with pre-existing heart disease. One patient who had ischemic heart disease was found to be extremely sensitive to weight changes; a weight gain of 3 to 4 lb. above his regular weight would precipitate congestive cardiac failure. The other patient who also had ischemic heart disease developed congestive cardiac failure due to inability to adhere to a low-salt diet, resulting in chronic over-hydration. The last patient's congestive cardiac failure was precipitated by a pulmonary embolism. He has mitral regurgitation as a result of erosion of a mitral valve which followed an episode of bacterial endocarditis. All were treated by fluid removal and digitalization only at the time of the acute episode. Digitalization was not instituted in the patient with chronic over-hydration. Only the patient with mitral regurgitation required maintenance digitalis. Treatment of hypertension in the first case contributed to the resolution of his congestive cardiac failure.

Metastatic soft-tissue calcification, which was present in two patients (Cases 3 and 9) when they entered the program, became more marked in one of these patients after 17 months.

Gout, involving the metatarsophalangeal area of the right foot, was encountered in one patient (Case 3) on two occasions. It resolved spontaneously.

Pruritus has been a problem in two cases, although all patients in the series except one have experienced this symptom in varying degree.

Gynecomastia was noted in four patients although this may have been present prior to chronic dialysis, since we have seen it in other chronically uremic patients who are not presently on the dialysis program.

Neuropathy, which has been described by others,⁶ has not been observed clinically in any of the patients in this series.

DISCUSSION

The feasibility of chronic hemodialysis to permit long-term survival of patients with end-stage uremia has been established by Scribner *et al.*¹ The program at the Montreal General Hospital is similar to that carried out in Seattle, in that patients are not being kept alive pending renal transplantation in the immediate future, as is the practice in some dialysis units. They are hemodialyzed simply to prolong life, although they will be considered for renal transplantation at some time in the distant future when transplantation is associated with a better survival rate. All of the patients in our series have survived for a period of at least one and one-half years.

Twenty-five serious complications of this procedure were encountered over the period of study. Of these, eight were due to septicemia and six further serious consequences resulted from blood-borne infections. Thus, of the 25 major complications, 14 (56.0%) resulted from septicemia or its sequelae. This underscores the seriousness of local infections at the shunt site, since in every instance of blood-stream infection a local infection preceded it. *Staphylococcus pyogenes* was the cause of all blood-borne infections. In most instances the infection was caused by a staphylococcus that the patient himself had harboured. The patient in Case 1, who has been on dialysis for two years, has not had a blood stream infection. This shows that the patient's ability to take care of his catheters has a significant influence on the occurrence of catheter-site infections.

As others have found, hypertension can be corrected by removal of excessive body fluid. In our experience, when the weight had increased, at times by more than 10 lb. above the patient's ideal weight, the blood pressure rose and the tissues of the face, limbs and other parts of the body became fuller, but no pitting edema was noted. However, residual hypertension persists in three of our patients. Two of these have considerable difficulty in adhering to a restricted salt diet, and one of them has the added problem of being anuric.

An attempt was made to determine whether running the dialysate circuit concurrent to the blood circuit resulted in a more efficient dialysis than did the procedure of running the dialysate circuit countercurrent to the blood circuit. Using the differences between the pre-dialysis and the post-dialysis creatinine and urea nitrogen levels as indices of efficiency of dialysis, no difference was noted between the two methods.

Serum hepatitis has not been a significant problem in our experience. Two patients developed this disorder within about 20 days of each other, but at the time that these patients had serum hepatitis

they were not being dialyzed together on the same days. Other patients who were dialyzed with the two who had the disease did not acquire hepatitis despite the fact that their dialysis fluid came from the same source. This observation suggests that the virus of serum hepatitis does not traverse the dialyzing membrane. An additional factor in this context is the viricidal effect of ultraviolet radiation used in our system.

Although it is possible to rehabilitate patients with terminal uremia to the extent that they may resume a productive and happy life with the aid of repeated hemodialysis, only 34 of the estimated 300 to 400 patients dying from uremia each year in Canada are now receiving the benefits of this type of treatment.⁷ The facilities for chronic dialysis are grossly inadequate and the cost is still relatively high. However, as units of this nature become larger, their cost diminishes. Our current expenses for a single dialysis are \$15, which includes the cost of all disposable equipment and chemicals used. If the salaries of personnel and the costs of purchase and maintenance of major items of equipment are taken into consideration, it is estimated that the cost of chronic hemodialysis at this unit is about \$7000 per patient per year.

SUMMARY

The experience of the Montreal General Hospital Chronic Dialysis Unit in prolonging the lives of 10 terminal uremic patients with repeated dialysis over the period of one and one-half years is described.

A modified Seattle system was employed and the actual dialyses were supervised by the nurses.

Of the 10 patients on the program, seven were male and three female. Their ages ranged from 29 to 52 years. The primary diseases leading to uremia were chronic

glomerulonephritis in eight and hereditary nephritis in two. All had creatinine clearances below 5 ml./min. at the time of admission to the program. All were hypertensive with symptoms or signs of heart failure and were anemic. Most of the patients were able to return to their jobs or carry on their usual domestic duties. Only one was unable to carry on as she had before the onset of uremia. Patients were dialyzed once to twice weekly for a period of eight to 12 hours overnight.

Complications fell into two main groups. The first was infections, most of which originated in the arterio-venous shunts. The second group included congestive heart failure, serum hepatitis, gouty arthritis, pulmonary embolism and persistent hypertension.

Continuation of a happy and useful life for terminal uremic patients by repeated regular dialysis is now a well-established fact.

ADDENDUM

As of December 1965, all patients are well and seven have passed or are close to two years on dialysis. All are now dialyzed twice weekly. Catheter infections have been rare with improved care and no further septicemias have occurred.

The authors wish to acknowledge the care and attention of the nursing personnel associated with the unit, and those on the 10 West nursing station, and the help of Miss J. Robb, the University Clinic dietician. The generous financial support and interest of the Women's Auxiliary is gratefully recognized and also the enlightened support throughout this program from the hospital and nursing administration. Finally, the encouragement and foresight of Dr. D. G. Cameron, Physician-in-Chief, is acknowledged. Without his enthusiasm this unit would not have existed.

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PAGES OUT OF THE PAST: FROM THE JOURNAL OF FIFTY YEARS AGO

A PATHWAY OUT OF THE WILDERNESS

The first essential in each of these patients is to make a diagnosis. To be led or misled by the symptoms given so much prominence is likely in each patient to lead to a life of chronic invalidism. An uncertain diagnosis betrays vacillation which is easily perceived by the patient, and is completely destructive of confidence and trust.

The terms employed to designate these psychic states are various and are used with a varying significance. The terms neurosis, psychoneurosis, neurasthenia, psychasthenia, nervous prostration, nervousness, nervous disorder, are terms whose significance varies largely according to the views of the writers employing them. There are some general characteristics, however, common to all the cases. There is always present, disharmony with the environment, a general impressionability, liability to suggestion, and, judged by fair average standards, a course of behaviour which betokens something below the level of safe, sound sanity.

It has been my practice to avoid detailed explanations at first, but to demand and secure obedience to my directions and to arrange somewhat minutely and arbitrarily how the hours and minutes should be spent. Always the patient must be lifted out of the old environment, from home, from affectionate, though unwise and harmful, domestic influence. The director of the gymnasium must be tactful, sympathetic and capable of exercising a positive but kindly discipline.

It is certain to be harmful to allow these patients to associate freely together. When we have had a number of them in the hospital at the same time there was shown a marked disposition on their part to flock together and talk about their troubles, thereby greatly accentuating them.

The parents and others in the home may have become convinced that there is an element of unreality and inconsistency about the patient, but uncertainty dogs their footsteps and nullifies every effort. They want a safe guidance which manifests no uncertainty, a voice that speaks with positiveness which gives them confidence that there is a pathway out of the wilderness of doubt.

Conduct that is insincere proves ruinous of that esteem on the part of the patient which is essential to success. Strange that it should ever be held and taught that deception toward these patients is justifiable; it is the sure road to loss of influence and consequent failure. Each fruitless effort to lift the patient from the slough of despond causes her to drop back, to sink deeper than before, where hope is less bright and prospects of eventful recovery more distant.

Though the practitioner sooner or later must follow such a course as will reveal the patient to herself, yet it is generally unwise to attempt to do so at first. The indirect mode of approach has manifest advantages; these patients must be fed with milk and not with meat, as they are not yet able to bear it.—B. E. McKenzie, *Canad. Med. Ass. J.*, 6: 131, 1916.