Home dialysis

Eight years' experience

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The first clinical use of the artificial kidney by Kolff in 1943 made it possible to prolong life by hemodialysis. Initially, this procedure was used mainly for patients with acute renal failure, since no permanent access to the blood stream was available. Long-term treatment of patients with chronic renal failure was made possible in 1960 when Quinton et al[1] developed the arteriovenous shunt. However, infection, clotting, and sacrifice of blood vessels continued to be major problems. Repeated access to the circulatory system was improved in 1966 when Brescia et al[2] described the technique for making a subcutaneous arteriovenous fistula. Saphenous vein loops[3] and bovine heterografts[4] have made long-term hemodialysis possible for patients with thrombosis of superficial veins.

Although the results of chronic hemodialysis were encouraging, it soon became apparent that the cost of hospital dialysis, even on an outpatient basis, was prohibitive. Consequently, the first Artificial Kidney Center was established adjacent to a community hospital in Seattle, Washington.[5] Limited care dialysis facilities are now in existence throughout the world. Home dialysis began to decrease the expense of chronic therapy; it was first used in Boston in 1963,[6] in Seattle and London in 1964,[7, 8] and at the Cleveland Clinic in 1966.

Table 1. Age and sex of patients

Age yr	Sex		Total
	Male	Female	
10–20	3	6	9
21–30	13	9	22
31–40	19	4	23
41–50	31	11	42
51–60	19	6	25
61–70	6	1	7
71–80	1	0	1
Total	92	37	129

Patient selection and clinical data

On January 1, 1975, the National Dialysis Registry reported that 12,977 patients were on chronic hemodialysis, 3,712 of whom were on home dialysis programs. This paper reports 8 years' experience with home dialysis patients.* Between January 1, 1966 and December 31, 1973, 129 patients were trained for home hemodialysis at The Cleveland Clinic Foundation. All patients were evaluated by a selection committee and accepted mainly on a first-come, first-served basis. Ninety-two men and 37 women and their spouses or family members were trained in a 2-bed home dialysis unit. Their ages ranged from 15 to 72 years (average age, 41.3 years). The youngest patients were between 15 and 20 years of age. Eight patients were older than 60 years; the majority, 42, were between 41 and 50 years of age (*Table 1*).

All patients had end-stage renal failure with creatinine clearances less than 5 ml/min/1.73 m^2 and required maintenance hemodialysis to stay alive. Chronic glomerulonephritis, chronic pyelonephritis, and polycystic kidney disease were the leading causes of renal failure in 76.8% of patients. The primary renal diseases are listed in *Table 2*.

The time between the date of diagnosis of renal disease and the beginning of either peritoneal dialysis or hemodialysis varied between 2 days and 47 years, (average time, 8.8 years). The diagnosis for 13 patients (16.3%) was made less than 1 year before maintenance dialysis was required; for 40 patients (31.0%) the diagnosis was made between 1 and 5 years. Eighty-

Table 2. Primary renal disease

Primary renal disease	No. of patients	
	Male	Female
Chronic glomerulonephritis*	37	10
Chronic pyelonephritis†	11	13
Polycystic kidney disease	18	6
Nephrosclerosis‡	11	3
Diabetes mellitus	4	0
Etiology undetermined	2	2
Analgesic nephropathy	2	0
Bilateral hypoplastic kidneys	0	2
Medullary cystic disease	2	0
Rapidly progressive glomerulonephritis	2	0
Amyloidosis	1	0
Cortical necrosis secondary to thrombosed renal artery in solitary left kidney§	1	0
Multicystic kidney disease‖	1	0
Hereditary nephritis	1	0
Total	93	36

* One patient had complete occlusion anterior branch of left renal artery; one patient also had nephrosclerosis.

† One patient also had nephrosclerosis.

‡ One patient also had focal glomerulonephritis; one patient also had left renal artery thrombosis.

§ Right nephrectomy for renal cell carcinoma.

‖ Patient also had chronic pyelonephritis and pyohydronephrosis.

* *At least a 1-year follow-up on all patients.*

Table 3. Duration of renal disease prior to beginning peritoneal dialysis or hemodialysis

Duration of renal disease, yr	No. of patients
<0.5	13
0.5–0.9	8
1–5	40
6–10	15
11–15	27
16–20	14
21–25	6
26–30	3
31–35	2
36–40	0
41–45	0
46–50	1
Total	129

two patients (63.6%) had renal disease from 1 to 15 years prior to dialysis; 26 (20.1%) had renal disease for at least 16 years before dialysis became necessary. The duration of renal diseases is further described in *Table 3*.

Circulatory access

To facilitate hemodialysis, permanent access to the circulation was performed either by arteriovenous shunts, arteriovenous fistulas, saphenous vein loops, bovine heterografts, or combinations thereof (*Table 4*).

Arteriovenous shunts were constructed in 42 patients; in 25 patients shunts were constructed in the forearm; in nine, in the leg, and in seven, both the forearm and the leg. Six of these patients had two or more shunts constructed in the forearm and one patient had two shunts constructed in the leg. The longest surviving shunt is a leg shunt that has been functioning for 93 months in a woman. The average shunt life has been 6 months.

Arteriovenous fistulas alone were constructed in 27 patients, either at the wrist between the radial artery and an adjacent vein or at the antecubital fossa between the brachial or radial arteries and the cephalic vein.[9] Two of these patients required construction of a second fistula because of technical problems with the first.

Fifty-two patients had both arteriovenous shunts and fistulas constructed. Initially, shunts were constructed in these patients. Arteriovenous fistulas were constructed later because of clotting and infection in the shunts, the sacrifice of multiple vessels by several shunt revisions, and arteriosclerosis in the arteries. In 33 of these patients the shunts were constructed in the forearms, in 11 patients in both the arms and the leg, and in eight patients in the legs only. Seven patients had two shunts in the arms and four patients had two shunts in the legs.

Table 4. Circulatory access

Type of access	No. of patients
Arteriovenous shunt	42
Arteriovenous fistula	27
Arteriovenous shunt and arteriovenous fistula	52
Arteriovenous shunt, arteriovenous fistula, bovine heterograft	2
Arteriovenous shunt, arteriovenous fistula, saphenous vein graft	2
Arteriovenous shunt, arteriovenous fistula, saphenous vein graft, bovine heterograft	2
Arteriovenous fistula, bovine heterograft	1
Arteriovenous fistula, saphenous vein graft	1
Total	129

Thirty-eight of the 52 patients had arteriovenous fistulas constructed at the wrist, 12 at the antecubital fossa, and two both at the wrist and at the antecubital fossa. Ischemia of the hand developed in two patients after construction of the arteriovenous fistula. The fistula had to be taken down on one of these patients. The longest surviving arteriovenous fistula has been in a male patient for 93 months.

Saphenous vein grafts were performed in five patients after failure of arteriovenous shunts and fistulas. Bovine heterografts were implanted in five patients after failure of the arteriovenous fistulas in three and failure of saphenous vein grafts in two.

Dialyzers and related equipment

The choice of an artificial kidney for home use depends upon cost, reliability, safety features, ease of setup, and efficiency. Initially, a quad coil disposable artificial kidney, with a washing machine as the tank, was used to train 12 patients for home hemodialysis.[10, 11] Its use was discontinued in 1967 because of poor ultrafiltration. Five of these patients were retrained to use the twin coil kidney and four, the Kiil dialyzer. The Kiil kidney was used as the main home dialyzer between January 1967 and January 1972, when the twin coil began to be used as the main training artificial kidney. The Kiil kidney had the advantage of low priming volume, low cost, and slower dialysis time. However, most patients became dissatisfied with the Kiil dialyzer because of the prolonged assembly and sterilization time. They felt that the reduced cost was not worth the time saved when other dialyzers were used. Subsequently, 12 patients transferred to the hollow fiber kidney (Dow). Since January 1972, our patients have been trained on either the twin coil or the hollow fiber kidney (*Table 5*).

Table 5. Type of dialyzers used

Type of dialyzer	No. of patients
Twin coil	53
Kiil	50
Kiil → Dow	10
Washing machine (quad coil)	5
Washing machine → twin coil	4
Washing machine → Kiil	3
Dow	1
Kiil → Gambro	1
Washing machine → Kiil → Dow	1
Washing machine → twin coil → Kiil → Dow	1
Total	129

All patients use deionizers at home to make certain the dialysis bath contains accurate chemical composition. All patients dialyze against a calcium concentration of 7.5 mg/100 ml to prevent renal osteodystrophy. Pressure is monitored from the venous drip chamber. Dialysis temperature and air detection devices are also used.

Home dialysis training

All patients were trained in special two-bed units separate from the main dialysis unit. The teaching staff (nurses and technicians) were selected according to their knowledge of dialysis, teaching ability, and interest in patient care. It is essential that the training personnel be understanding, and that the patient and family member be instructed in the technique of dialysis slowly, so that they can develop self-confidence. In our experience most patients can be trained. We have trained patients who could not

speak English and those who could not read. Training these and the elderly and less confident patients takes a much longer time. We have found, as others have, that motivation is the key to success in home dialysis training.[12] The intelligence and background of the patients do not correlate with the degree of success of home dialysis.

Each patient has been given a Home Dialysis Manual which describes the program at the Cleveland Clinic. This manual introduces the subject of chronic renal failure and how it affects the body. The dialysis techniques are described, medications are listed, and definitions of words that become part of the patient's vocabulary are included.

The training time for all patients is listed in *Table 6*. It ranged from 5 to 34 weeks (average 13 weeks). Fifty-seven patients (44.2%) completed their training between 6 and 10 weeks; 107 patients (82.9%) completed their training in 16 weeks or less; 22 patients (17.1%) required training time between 17 and 34 weeks.

Table 6. Dialysis training time

Training time, wk	No. of patients
1–5	1
6–10	57
11–16	49
17–20	10
21–25	6
26–30	4
30–35	2
Total	129

Results

Of 129 patients on the Home Dialysis Program, 63 are alive and 66 have died. Survivals for 1 year were 84.27%; 2 years, 71.0%; 3 years, 59.8%; and 4 years, 50.4%. Survival data are shown in the *Figure*. Survival probability within each year of the analysis remained the same. The differences in the probabilities in each year were due to random sampling. The constant probability of survival for each year is 0.8425; the survival curve equation is 0.8425 raised to the power of the number of years of interest.

Sixty-two patients underwent hemodialysis alone and 67 patients were on peritoneal dialysis for a period ranging from 1 week to 13 months before transfer to hemodialysis. The average time for all patients who underwent hemodialysis alone or a combination of peritoneal and hemodialysis was 37.9 months (*Table 7*). Total dialysis time includes pretraining, training, and posttraining times, until dialysis was discontinued, the patient transferred to another center, received a kidney transplant, or died.

The average dialysis time at home for the 129 patients was 28.7 months. Forty (31.0%) of the patients were at home for 1 year or less. *Table 8* lists the reasons for discontinuing home dialysis. Of the 31 patients who died when on dialysis less than 1 year, 48.4% died of cerebral bleeding or infection.

Eighty-seven (67.4%) of the patients were on home dialysis for at least 1 year; 58 (44.9%), 2 years; 40 (31.0%), 3 years; 28 (21.7%), 4 years; 20 (15.5%), 5 years; 11 (8.5%), 6 years; 6 (4.7%), 7 years; and 1 (0.78%), 8 years (*Table 9*).

Home dialysis had to be discontinued in nine patients. One patient transferred to the Hospital for outpatient dialysis and four to the

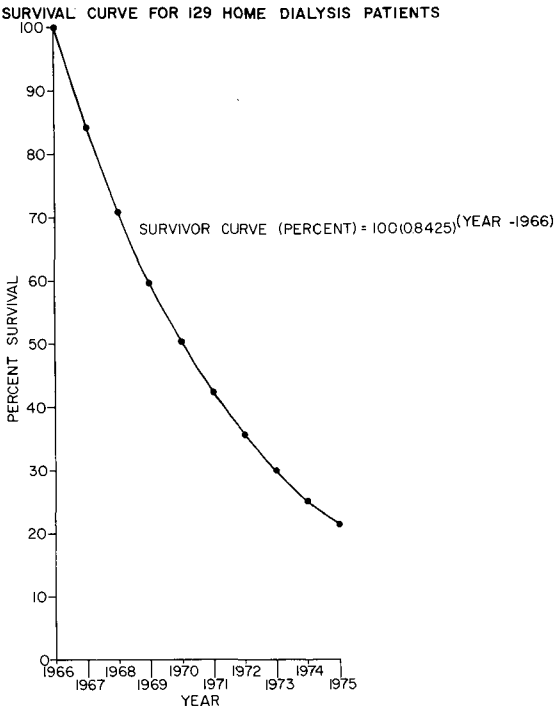

Figure. Survival data for 129 home dialysis patients.

Table 7. Total dialysis time

Length of time, mo	No. of patients
<6	2
6–12	19
13–24	25
25–36	26
37–48	19
49–60	14
61–72	10
73–84	7
85–96	4
97–108	3
Total	129

Limited Care Facility because of psychologic problems. Three patients transferred to the Limited Care Facility because of a combination of circulatory access and psychologic problems. One other patient transferred to the Limited Care Facility because the family member carrying out dialysis became pregnant, and because no other member was able or willing to continue the dialysis at home. These patients had been on home dialysis for 3 to 32 months (average, 13.9 months) before transferring to the Limited

Table 8. Cause of discontinuing home dialysis in less than 1 year in 40 patients

Cause of discontinuing dialysis	No. of patients
Died	31
Kidney transplant	6
Limited care facility	2
Hospital outpatient dialysis	1
Total	40

Care Facility or hospital outpatient dialysis. Two patients transferred to other centers for financial reasons. Two patients were transferred to home peritoneal dialysis because of lack of vascular access after being on home hemodialysis for 56 and 63 months respectively. One patient transferred to the hospital for outpatient peritoneal dialysis after 3 months of home hemodialysis because his spouse had failing vision.

Table 9. Total home dialysis time

Length of time, mo	No. of patients
<6	25
6–12	19
13–24	28
25–36	20
37–48	10
49–60	7
61–72	9
73–84	5
85–96	5
91–108	1
Total	129

Complications

Most complications in our patients involved the cardiovascular system. Hypertension, the major complication, affected 86.0% of the patients: 74.8% of the hypertensive patients or 63.4% of all the patients had hypertensive cardiovascular disease. One to three episodes of congestive heart failure were experienced by 78.3% of the patients. Pericarditis developed in 38 patients (29.5%); 60.5% of these patients had pericardial effusions. Cardiac tamponade developed in 21.1%; four patients died of cardiac tamponade. Pericardial windows were performed in 14 (36.8%) of the patients with pericarditis. Thirty-one patients (24.0%) had arteriosclerotic heart disease. Twelve (38.7%) of these patients had remote myocardial infarctions and 22.6% experienced one or two acute myocardial infarctions. Other cardiovascular complications are listed in *Table 10*.

Forty-one patients (31.8%) had one or two episodes of gastrointestinal bleeding. Gastritis was the major cause of the bleeding in 32 (78.0%) of these patients. Peptic ulcers documented by roentgenography were the cause of gastrointestinal bleeding in five patients (16.1%). Coumadin therapy administered to prevent clotting of arteriovenous shunts accounted for gastrointestinal bleeding in two patients. One patient had gastric erosions.

Serum hepatitis developed in 17 (13.2%) of the patients. Hepatitis was much milder in these patients than in the personnel. All patients recovered without complications. Pancreatitis developed in eight patients; other gastrointestinal complications are listed in *Table 10*.

Infection was the major cause of death in 76 patients (58.9%). Pneumonia was the main source of infection in 32.6% of all patients and 55.3% of all the infected patients. Septicemia, the second major source of infection developed in 32.9% of all infected patients and 19.4% of all patients. Shunt infections were the source of infection in 7 of the 12 patients with gram-positive septicemia (*Table 10*).

Cerebral complications are listed in *Table 10*. The major cerebral complications were uremic encephalopathy, 11.6%; cerebral bleeding, 8.5%; seizures, 5.4%; and cerebral infarction, 3.9%.

Table 10. Complications

Complication	No. of patients
Atherosclerosis	
Aorta	6
Generalized	3
Carotid	2
Cerebral, diffuse	2
Femoral artery*	2
Cardiovascular	
Hypertension	111
Hypertensive cardiovascular disease	83
Congestive heart failure	101
Pericarditis	38
Arteriosclerotic heart disease	31
Remote myocardial infarction	12
Acute myocardial infarction	7
Pericardial effusion	23
Cardiac tamponade	8
Cardiac arrhythmia	7
Cardiac arrest secondary to hyperkalemia	5
Subacute bacterial endocarditis with ruptured aortic valve	2
Pericardial abscess	1
Ruptured ascending aortic aneurysm	1
Ventricular aneurysm	1
Cerebral	
Uremic encephalopathy	15
Cerebral bleeding	11
Seizures	7
Cerebral infarction	5
Cerebral vascular accidents	2
Transient cerebral ischemia	2
Alzheimer's disease	2
Cerebellar tonsillar herniation	1
Disequilibrium syndrome	1
Hypertensive encephalopathy	1
Retinal vein occlusion	1
Gastrointestinal	
Gastrointestinal bleeding	41
Gastritis	32
Ulcer	5
Coumadin induced	2
Gastric erosion	1
Multiple petechial hemorrhages	1
Hepatitis	17
Pancreatitis	8
Peritonitis	5
Diverticulosis	3
Splenitis	3
Bowel obstruction	2
Acute diverticulitis with perforation	1
Esophagitis	1
Hemorrhage, peripancreatic, periadrenal and duodenal, mesentery	1
Hiatal hernia	1
Proctosigmoiditis	1
Retroperitoneal angiolymphoid hematoma	1
Splenic infarction	1
Uremic enteropathy	1
Gynecologic	
Menorrhagia	8
Infection	
Pneumonia	42
Septicemia	25
Gram-negative 12	
Gram-positive 12	
Yeast 1	
Bronchitis	3
Empyema	1
Infectious arthritis	1
Infected teeth	1
Infected vertebral disc	1
Pulmonary abscess	1
Subphrenic abscess	1
Genitourinary	
Hemorrhage, polycystic kidneys	2
Prostatitis	1
Prostatic vein thrombosis	1
Urethral stricture	1
Radiation cystitis	1
Gout	7
Hyperparathyroidism	102
Osteomalacia	81
Peripheral neuropathy	93
Pulmonary	
Pleural effusion	19
Pulmonary edema	11
Pleuritis	7
Pulmonary emboli	4
Respiratory failure	2
Hemorrhage	2
Hemosiderosis	1
Infarction	1

* Bilateral in one patient.

Pulmonary complications occurred in 47 patients. Thirty (23.3%) of all patients had episodes of pulmonary edema or pleural effusions. Pleuritis developed in seven patients and pulmonary emboli in four. Other pulmonary complications are listed in *Table 10*.

Fifteen (11.6%) of all patients had significant atherosclerosis. The aorta was the major site of atherosclerosis in these patients. It was generalized in three patients (*Table 10*).

Eight of 37 women had menorrhagia. Radiation cystitis requiring a cystectomy because of severe bleeding developed in one patient who underwent irradiation to control the bleeding.

Seven patients had one or more episodes of gout. All of our patients received allopurinol to control the uric acid content of the blood; those who had gout were either unable to take allopurinol or did not take it regularly.

Genitourinary complications occurred in six patients. Two patients who had polycystic kidneys hemorrhaged severely and one of these patients died. Other genitourinary complications included prostatitis, prostatic vein thrombosis, urethral stricture, and radiation cystitis (*Table 10*).

Although all patients had peripheral neuropathy by nerve conduction studies, 93 (72.1%) had clinically evident neuropathy.

Renal osteodystrophy was a significant problem, clinically and roentgenographically; 102 patients (79.1%) had secondary hyperparathyroidism. Ten underwent subtotal or total parathyroidectomy. Eighty-one (62.8%) had osteomalacia. Renal osteodystrophy has been better controlled during the past several years because of earlier therapy with antacids (prior to beginning dialysis therapy), increasing the calcium content of the dialyzing solution to 7.5 mg/100 ml and therapy with vitamin D when indicated. Severe bone disease seen in the early 1960s is rarely seen in our institution today (*Table 10*).

Psychologic problems

In our experience the success or failure of the Home Dialysis Program does not depend upon the education of the patient and his spouse or family member, but on the determination to succeed. In each family, there is usually one member who excels in giving psychologic support to the patient. When there is no such member, the patient frequently is unable to cope with the stress of having his life depend upon a machine and serious psychologic problems result.

Many of the home dialysis failures were secondary to psychologic problems. Seventy-three (56.6%) of our home dialysis patients had significant psychologic problems. These problems were minor in 24.0%, moderate in 12.4%, and major in 20.2% (*Table 11*).

Major problems were defined as those which required constant intensive psychiatric support or medication, hospitalization in the psychiatric unit of the hospital, or problems which led to discontinuation of the Home Dialysis Program. Moderate problems were those which required intermittent psychiatric support or medication, but with the patient functioning normally between episodes. Minor psychiatric problems were those episodes of minor depression which did not require psychiatric support or medication and

Table 11. Psychological problems

Problem	No. of patients
Minor	31
Moderate	16
Major	26
Total	73

with which the patient could cope himself.

Fifty-six patients (43.4%) did not have psychologic problems. These patients were depressed only when they were initially told that they had end-stage renal failure requiring maintenance hemodialysis. They coped well thereafter and were rehabilitated.

The nursing staff, dialysis technicians, and physicians must constantly be on the alert for early signs of psychologic problems in these patients. Often it is a family member who alerts the staff to these problems. The patient frequently denies them, but when directly approached will often admit to them. A great amount of patience, understanding, and empathy are required of all personnel and physicians caring for home dialysis patients.

Rehabilitation of patients

One of the major concerns of physicians treating patients with chronic renal failure is the rehabilitation of these patients during chronic dialysis therapy. Chronic tensions associated with long-term illnesses often prevent patients from being satisfactorily rehabilitated. Sixty-six (51.2%) of our patients were fully rehabilitated. Twenty-five (19.3%) were partially rehabilitated. Thus, a total of 91 patients (70.5%) were either partially or fully rehabilitated. Thirty-eight patients (29.5%) were either medically retired or unemployed. *Table 12* more fully describes the rehabilitation of our home dialysis patients.

Mortality

Sixty-six patients (51.2%) died. Infection was the leading cause of death in 27.3% of these patients. Nine patients (13.6%) died of cerebral hemorrhage, 9.1% of myocardial infarction. Thirteen deaths (19.7%) were due to cardiovascular complication. Dialysis was discontinued in one patient because of a progressive deterioration of the clinical condition. One patient committed suicide and accounted for only 1.5% of the deaths (*Table 13*).

Conclusion

The patient with end-stage renal failure faces many social, psychologic, financial, and medical problems. Adequate psychologic support must be provided by the patient's family, the physician, nurses, technicians, and social workers. Team effort is essential for successful home dialysis.

Table 12. Rehabilitation

Status of patients	No. of patients
Full-time employment	42
Part-time employment	9
Normal activities	
Homemaker	13
Retired	3
Student	8
Restricted activities	
Homemaker	11
Retired	4
Student	1
Medically retired	13
Unemployed	25
Total	129

Home dialysis has several advantages. Patients feel better in a home environment where they are not constantly reminded of their illness as is the case in the hospital. They can schedule dialysis to accommodate their daily routines. This gives the patient more "control of his life," for he is not at the mercy of last minute schedule changes which occur in dialysis centers. No time is expended in traveling to and from the center. Thus, the patient has more time to spend with his family, at work, and performing other routine and pleasurable activities of everyday life.

Rehabilitation of patients requires much effort by the dialysis team. Many patients have lost self-confidence. Others, unfortunately, have been told that they must accept medical retirement, even though it may not be necessary; financial problems thus develop. As a result, many patients become depressed and feel that they no longer have control of their lives. Some feel that life is not worthwhile. Only one of our patients committed suicide. Intensive psychologic support is necessary during this period of adjustment.

Education of employers is necessary. They often feel that the patient who is alive as a result of dialysis is "too sick" to work. Their lack of understanding certainly undermines the patient's self-confidence, so once again he is reminded that he is sick and different from other people.

Ninety-one (70.5%) of our patients were fully or partially rehabilitated. Thirteen (10.1%) were medically retired and 25 (19.4%) were unemployed. Sixty-three (48.8%) of our 129 patients are alive and 66 (51.2%) have died.

Whether patients with end-stage renal failure should be treated at all is still controversial. Indeed, if they were not treated, one must also consider the fact that other patients with debilitating and terminal illnesses should also not be treated. Rehabilitation and survival statistics of chronic dialysis patients have been most encouraging and leave little doubt as to the effectiveness of dialysis therapy.[13-18]

Although hemodialysis therapy has improved greatly during the past decade due to technical advances and better circulatory access, one must not lose sight of the fact that successful home dialysis is dependent upon the courage and resourcefulness of the patient and family members, and the psychologic support of the patient by his family, friends, and physician. Without these, no home dialysis pro-

Table 13. Mortality

Cause of death	No. of patients
Infection*	18
Unknown	10
Cerebral hemorrhage	9
Myocardial infarction	6
Cardiac tamponade	4
Gastrointestinal bleeding	4
Hyperkalemia†	4
Respiratory failure	2
Acute pulmonary edema and hemorrhage	1
Cardiac arrhythmia	1
Corpulmonale	1
Discontinuing dialysis	1
Hemorrhage, arteriovenous fistula	1
Hemorrhage, polycystic kidneys	1
Hypoglycemic shock	1
Ruptured aortic aneurysm, ascending aorta	1
Suicide	1
Total	66

* One patient also had respiratory failure.
† One patient was also hypocalcemic.

gram could be successful regardless of technical advances.

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