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Artificial kidney : a discussion of the history and technical management with the use of the Kolff stationary coil kidney

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THE ARTIFICIAL KIDNEY

A DISCUSSION OF THE HISTORY AND TECHNICAL MANAGEMENT WITH THE USE OF THE KOLFF STATIONARY COIL KIDNEY

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INTRODUCTION

A modified Kolff Stationary Coil type artificial kidney has been in use at the University of Nebraska Medical Center since December of 1956. Under the direction of the staff, several medical students (J. C., R. B., R. O.) began experimentation with this unit. It was our aim that the mechanical and physiological problems connected with dialysis with this type of artificial kidney would in this way be solved and this unit would become a practical clinical unit. This group had, by the end of December, worked with several dogs and some of the mechanical problems were becoming apparent. It was at this developmental stage that a seriously ill patient, indeed in the final stages of uremia, presented himself at University Hospital and because of his poor clinical status, dialysis was undertaken. Since this first successful dialysis this unit has been used a total of ten times at this and associated institutions.

The purpose of this paper is to present to the reader a short history of the development of the artificial kidney, to describe the particular type unit in use at this institution and the Bishop Clarkson Memorial Hospital, to outline the indications and contraindications for its use, to describe some of the problems that develop with the use of such a unit and in general give the reader an overall picture of dialysis and what it entails.

HISTORY

An instrument capable of maintaining hemeostasis, as do the kidneys, has long been desired by the medical profession. Many attempts have been made and as many different approaches have been used.(1-2) I will not attempt to discuss peritoneal lavage, intestinal lavage, exsanguination transfusions and the like in this dissertation; rather, I shall confine my remarks to the artificial kidney.

In 1912, Abel, Roundtree and Turner(3) working in the laboratories at Johns Hopkins Medical School made the first real dializer that was constructed so as to have the primary qualifications of an artificial kidney as it is known today. This unit, which was the grandchild of many attempts, was a many-tubed affair. The tubes were made of colloidion, which served as the semipermeable membrane. They were 6-8 mm. in diameter and 25-50 cm. in length. These were assembled in batteries of 8 to 10 which were in turn hooked to a common channel to which an artery was connected. The other end of the system was connected to the venous return and in this way an artificial A-V shunt was obtained and the blood was in a crude form of what we term today dialized. This battery of 8 to 10 tubes was held in a glass mantel around which was circulated the dialysate (hypotonic saline was used most often.) Thus the blood flowing through the collodion tubes was forced through by the arterial pressure of the animal. These tubes were bathed with hypotonic solutions and in this way, through osmosis, several substances were obtained from the blood and subsequently identified.(4) Hirudin, which had been extracted from the heads of leeches, was used as an anticoagulant in this work.

This pioneer work showed that such substances as urea and the salisylates could be removed from the circulating blood without harm to the animal or the circulating elements.

Thus the search for a clinical unit was started, and here it stopped; for it was obvious to these workers that the lack of a suitable semipermeable membrane and the need for a safe, plentiful anti-coagulant were the limiting factors in the building and use of such a unit.

Thirty years later Kolff carefully reviewed Abel, Roundtree and Turner's work and stated that "an ideal vividialysis must fulfill the following demands: 1. the blood must be kept in a closed system outside the body; 2. it must be possible to sterilize this system; and 3. the blood must be kept liquid in a harmless way."(5)

At this time and independently Alwall in Sweden and Murray in Canada had developed different types of artificial kidneys, but it was Kolff who spent most of his time in this work, who came to realize that the consistent intolerance to dialysis as seen in dogs was not necessarily a manifestation in humans. It was his unit, the rotating drum type of artificial kidney, that received recognition throughout the world, and has since undergone numerous modifications and in its final plan was used quite extensively during World War II and the Korean War.(6)

Subsequently many other units have been developed. Among them was the Skeegs-Leonard(7) variation which was one of the first units to apply hydrostatic pressure to the circulating blood and in this way produce ultra-filtration of the fluid and with it the solids from the circulating blood to the dialisate. This change greatly increased the efficiency of the kidney as it produced an increase in the clearance rate and allowed for a decrease in the surface area of the semipermeable membrane.

Later Kolff developed his stationary coil type kidney which is the unit used at this institution.(8) This unit employs the principals of other artificial kidneys; that is, the patient's blood is circulated through a channel of semipermeable membrane while the dializing fluid circulates outside the coil. This coil is made of cellulose (viscine sausage casing) which is held in a space of specific volume by placing figerglass screens on either side. The screen and the tubing are wound together into one coil. The screens in this way allow for a minimum of expansion of the tubing which is more or less predetermined by placing spacers (strips of screening) in the space occupied by the membrane. The blood is propelled through the semipermeable membrane at a rate of 200 cc. per minute by the Sigma Motor Pump.(9) At the same time the dialysate is circulated through the coil so as to bathe the semipermeable membrane. In this way exchanges of substances lacking in either medium, blood or the dialysate, are transferred to the other medium until they reach an equilibrium. (the principal of osmosis.)

The diagram below shows a cross-section of this membrane and its separating screens.

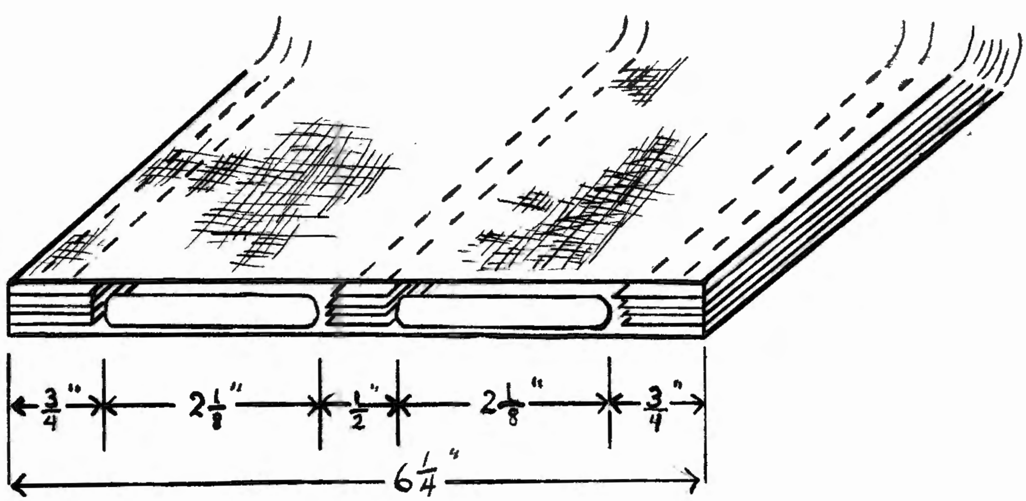

Figure I.

Nylon tubing is tied into the ends of this celluloid tubing for the inflow and outflow of blood.

This unit is then wrapped around a can (large fruit juice can). The arterial end (or inflow tract) is allowed to stick through the sides of the can, and with the completion of the coil the outflow ends (venous ends) are on the outside of the coil. We have then two lengths of semipermeable membrane, each 10 meters long, that have been wrapped around this can.

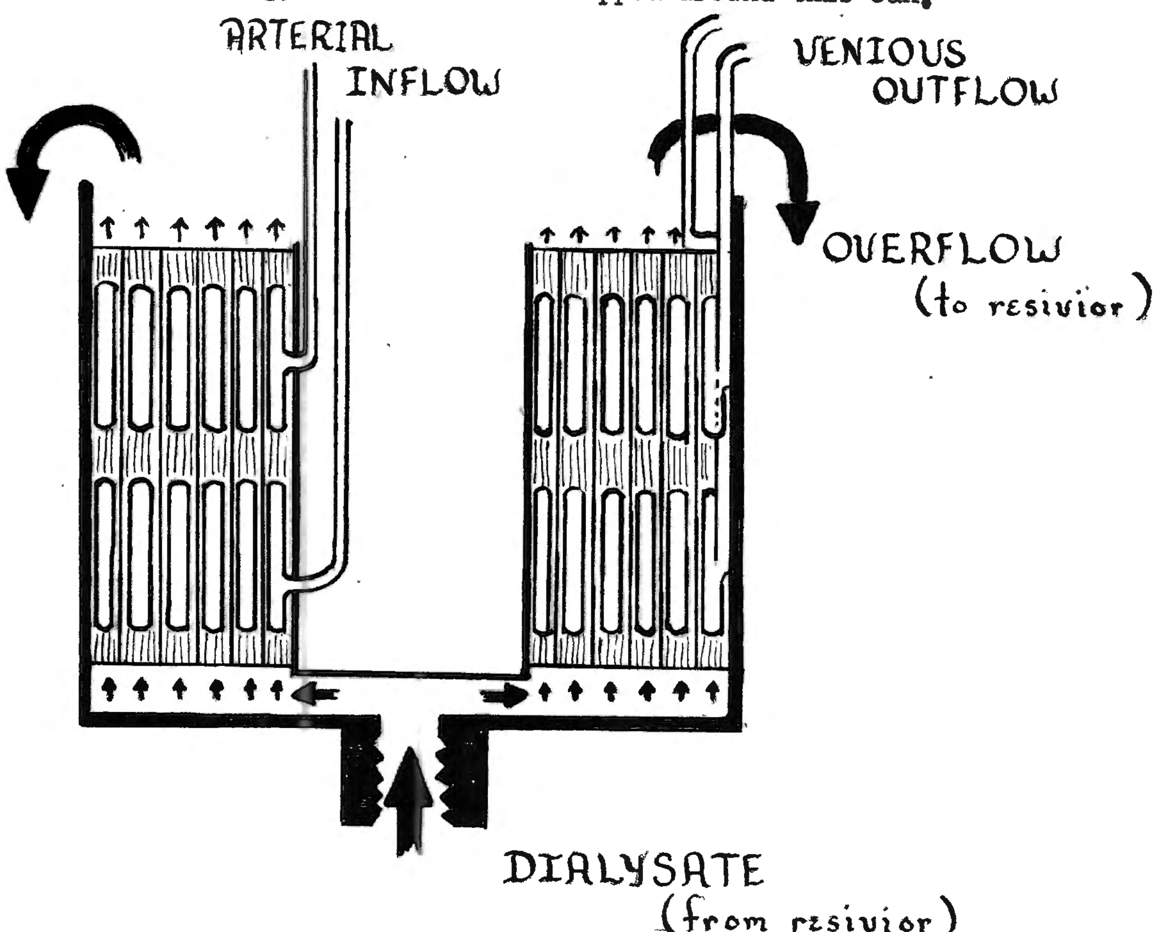

Figure II.

This unit is then incorporated into the pumps and dialyzing fluid reservoirs as shown in Figure III.

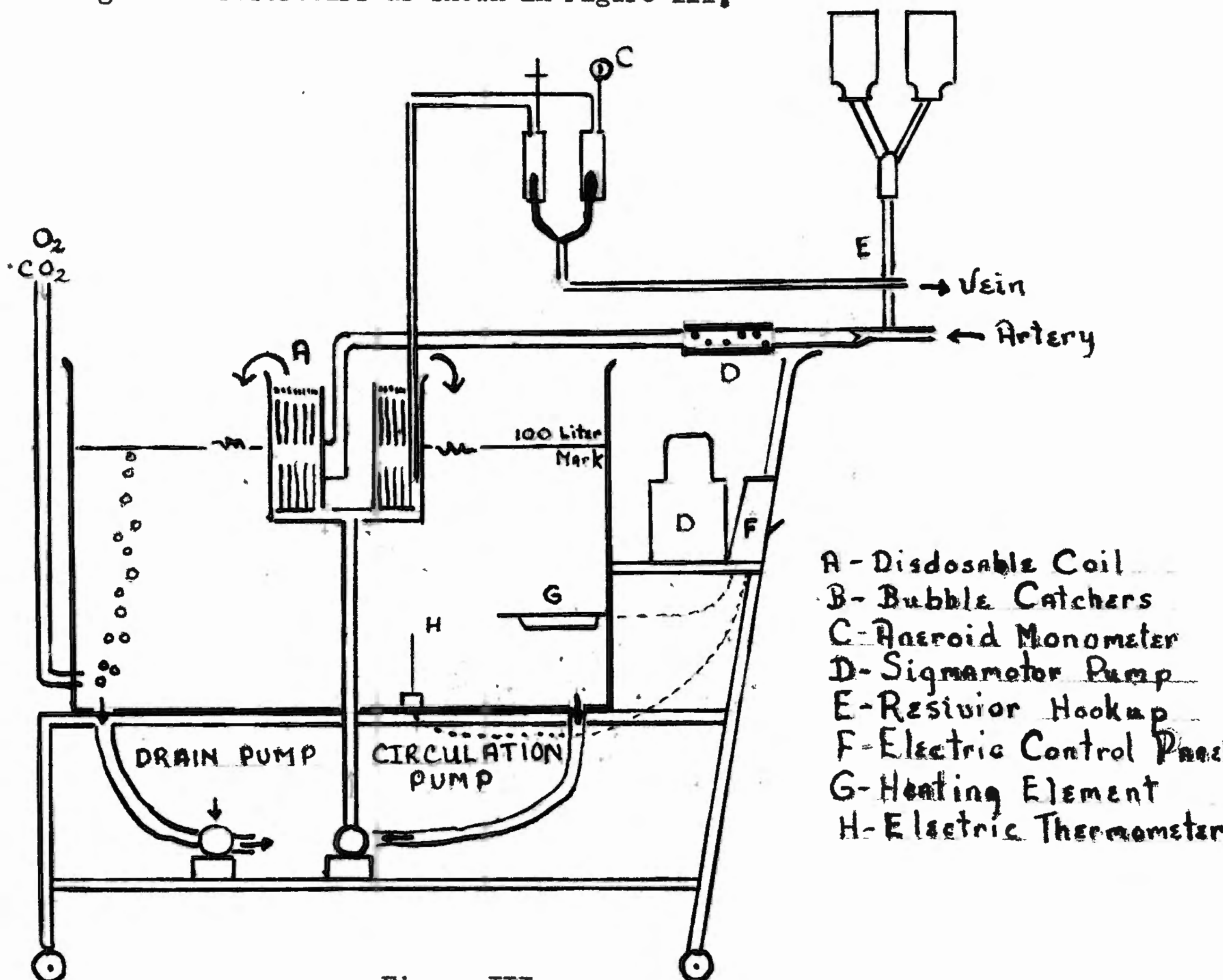

Figure III.

FUNCTIONS OF THE COIL KIDNEY

The resistance to the flow of blood in this artificial kidney varies with the smoothness of the coil, the length of the coil and the thickness of the spacers. By these dimensions then it is simple substitution that 1. a smooth, non-kinking coil, 2. as short a tubing as possible, and 3. the volume of the membrane would affect the flow of the blood through the unit. Kolff, after considerable experimentation with these dimensions, chose the flow rate of 100 cc. per minute. It was chosen because in using his coil that had 1. been wrapped around a can to insure smoothness, 2. was ten meters in length, and 3. was contained within the screening between three spacers and thus of small volume, he noted that the clearance of urea from a solution that was dialyzed against tap water, reached its peak clearance at this rate of flow.(10) This would seem to indicate that the exchanges were being accomplished at their fastest rate at this flow rate. This clearance rate is then stated as being of the magnitude of 70 to 80 ml. per minute when 10 meters of tubing are wrapped around a specific size can and the flow rate is 100 cc. per minute.(11)

He then, because this is a twin coil kidney, states that this clearance may be doubled, for indeed the flow of the urea solution would be doubled by using a double-barrelled unit. Perhaps some doubt may be cast regarding these clearance values of 140 to 160 cc/min. Are they valid? They are not realized in clinical practice. Would not the dialysate also reach a saturation point? Kolff did his work using a single coil and although it is not stated, he probably used a constant rate of dialysate flow. (The same rate used with a twin coil.) Perhaps this question of dialisate flow should be as thoroughly evaluated as was the question of the rate of flow of blood through the membrane.

In this same work Kolff stated that hydrostatic pressures of 140 to 160 mm. of mercury were necessary to produce flows of 100 cc. per minute. There exists than at flow rates of 100 cc. per minute pressures within the membrane of 140 to 160 mm. of mercury. This hydrostatic pressure will produce ultrafiltration; that is, pressure inside the membrane causing a loss of fluids and with it solids from the fluid in the membrane to the bathing fluid, or in truth from the blood to the dialysate. The magnitude of this value and the ramifications it may have on water balance with prolonged dialysis had not been determined.

In describing this function, it is stated that ultrafiltration of the magnitude of 200 to 300 ml. per hour is obtained.(12) With this in mind it may be desirable to augment the rate of ultrafiltration in cases that show evidence of over-hydration. This is achieved by simply placing a screw clamp on the outlet flow tract. In the Amer. J. of Ped.(13) Kolff states that with pressures of 250 mg. of mercury, (measured at the bubble catcher) will produce ultrafiltration of nearly 700 ml. per hour. No mention is made regarding specific studies along these lines, but in direct communication with the authors of this paper, it is our understanding that this work was done with a saline solution against a tap water bath.

We have then a kidney that functions by ultrafiltration, as just described, and by simple osmosis in that the bathing fluid (dialysate) is chemically constructed so as to add substances that may be lacking in the blood medium and by the same mechanisms, remove any foreign intoxicant or any substance in over-abundance (potassium in uremia).

Perhaps as important a consideration in this discussion is a mention of the priming volume of this unit. Using ten meter lengths of cellulose tubing that are confined in a space provided by using three spacers, a single length of tubing will require approximately 375 cc. of blood as a primer.

Doubling this value we see that to prime this unit 750 cc. of blood must be used. We are able to predetermine then that the volume of the membrane and the amount of variation in this volume should be very small because of this predetermined distensibility. This has merit in that it is not possible to exsanguinate a patient into a machine as was possible in the older form of Kolff kidney. The simplicity of design that is employed in this unit is also a decided advantage over its predecessor.

THE INDICATIONS FOR DIALYSIS

a. Renal:

There exist in this regard two distinct schools of thought. One group of internists and urologists feel that anything the dialysis may have accomplished would have been forthcoming with less drastic methods (i.e. resins, etc. in conjunction with good medical management). On the other hand it is the opinion of those that have worked with dialysis that this procedure is definitely indicated in any of the many medical-urological conditions wherein the proper laboratory and clinical deteriorations have developed. Lukemeyer and Heuber(14) give an impressive list of conditions in which dialysis has been used. In all these clinical entities, metabolic inbalance had progressed until either the serum potassium has risen to 7.0 milliequivalents per liter, the CO_2 combining power had fallen to 10-12 milliequivalents per liter or the BUN had risen to 300 mg. per cent. Kolff(15) in a recent work has evidently lowered these requirements and indeed perhaps many of the other working teams may consider dialysis before the deterioration has developed to this severe degree. We have then a biochemical indication for dialysis. It is felt that in many instances to wait for these conditions to develop increases the morbidity of the patient to such an extent that the previously mentioned "lowering of standards" may be of considerable merit. In essence then, in any condition wherein these changes or a combination of them developes, dialysis should be carried out, even though the inciting cause be as varied in origin as acute lower nephron nephrosis or chronic gromerular nephritis.

It is readily understood how dialysis can be helpful in such an instance of lower nephron disease, that is, by helping the patient over the hump in this acute disease. However, in the case of chronic renal disease, the question is often asked "How can this dialysis be of help when the disease process is not altered, arrested, or resolution accomplished?" Most investigators feel that dialysis is indicated because it is in many instances an acute exacerbation of his chronic disease or in many cases the clinical improvement produced in these people is much greater than their renal function or their laboratory improvement would indicate. Perhaps in answer to this question we must remind ourselves that this is a manifestation of whole body chemistry rather than the circulatory volume alone. Also, there are many unknowns in this process of dialysis and the changes wrought by this manipulation may one day be more clearly understood.

In addition to the chemical deterioration already mentioned Kolff(16) speaks of clinical criterion for dialysis. He believes that there are usually one of two existing clinical behavior patterns. In the first, lethargy, apathy and somnolence; in the second, there may be restlessness, irritability and psychosis. Either pattern may be associated with nausea, vomiting and alteration of the cardiovascular status, especially manifest as wide ranges in blood pressure, both hypotensive and hypertensive.

Generally speaking then, in severe uremia, a state is reached where conservative procedures become inadequate. With progression of the uremic process, there begins a vicious cycle. Physical degeneration adds pathologic changes to an already very delicate therapeutic problem. Vomiting for example makes caloric intake difficult to determine and disturbs electrolyte balance. Coma prevents expectoration and promotes pulmonary infection. Insufficient caloric intake, electrolyte disturbance and infection all enhance uremia. Therefore, early dialysis should be undertaken in order that this cycle be stopped or uremia be curtailed before the cycling can begin.

In summary then the indications for dialysis in renal diseases are considered to be clinical and chemical. These conditions are generally quite obvious and easily assayed and although dialysis has not proven to be dangerous, it is the feeling of this group that these conditions should be met before dialysis is undertaken.

b.) Intoxications:

Other indications for dialysis are acute intoxications. This therapy appears to be one real rational method of treatment of acute barbiturate intoxication. Alwall (17) in 1952 was one of the first to experiment with this intoxication. He reported the treatment of three groups of rabbits poisoned with phenobarbital. He used forced diuresis, ultrafiltration and hemodialysis in the treatment. Also reported at this time were accounts of dialysis of two human subjects with "severe intoxication." He reported that "the blood barbiturate level was lowered sixty to seventy per cent" but the specific barbiturate was not identified. In regard to his animal work he showed quite conclusively that dialysis was by far the best treatment for acute barbiturate intoxication. Along this same line, in 1953 Kyle and others (18) reported on the use of the Kolff rotating dialyzer in the treatment of two patients who had ingested pentobarbital (nembutal) and amobarbital (amytal.) In the first mentioned, clinical improvement was noted during the procedure with return of the deep tendon reflexes and rise in the blood pressure. The patient was dialyzed five yours with the blood barbiturate level falling from 5.9 to 3.0 mg. per cent and a total of 720 mg. of the barbiturate was recovered. In the second case the blood level fell from 5.2 mg. to 3.5 mg. per cent and 300 mg. of the barbiturate was recovered. There was a simillar improvement in this patients' clinical status after a dialysis of four and one half hours.

Perhaps a better idea of the rate of dialysance of the barbiturate was realized through the work of Sunshine and Leonards. (19) They had poisoned dogs with pentobarbital, phenobarbital and amobarbital and then treated these animals with the Skeegs-Leonards apparatus. They then compared their dialyzed animals with control animals (also poisoned) watching their blood barbiturate levels, their relative recovery times and the mortality rate. The amount of the drug recovered in the dialyzing solution averaged forty percent for phenobarbital, twenty per cent for pentobarbital and thirty-five per cent for those given amobarbital. The clinical improvement was found to be most striking in that group that received phenobarbital or, in other words, the longer acting agent.

In 1956 Berman(20) reported on twenty-six cases of barbiturate intoxication, seven of which were serious enough to be treated with hemodialysis. They reported recoveries very nearly the same as those just referred to. (Sunshine and Leonards). In their series they stated that they felt that one life was unquestionably saved by the process, that the period of coma was unquestionably shortened in others, and that in the cases of the short acting drug the blood levels were lowered from fatal levels.

This would seem to indicate then that the treatment of acute barbiturate intoxication is effectively handled by dialysis. It is felt that this is a rational and highly effective method of treatment. The risk of the procedure is not felt to be a deterrent when in the hands of adequately trained personnel and that dialysis is worthy of clinical application in two situations: namely, when the amount ingested or the blood level is clearly in the potentially fatal range for the bartiturate in question and when the physical state is likely to increase the hazards of coma. In this last indication we are saying in effect that the reduction of morbidity is as legitimate an indication for dialysis as is the reduction of mortality.

Bromidism:

In 1952 Merrill(21) reported on a case of bromidism that he had treated with dialysis. The patient had a history of thirty years of consumption of bromides and had been admitted to a psychiatric hospital. (Peter Brent Brigham). Blood bromide levels were found to be

23 mg. per cent. The patient was described as lucid, disoriented, and had developed paranoid tendencies. Dialysis for five hours lowered the serum bromide to 3.3 mg. per cent. There was prompt return of cerebral function following dialysis. The treatment of bromidism is not an emergency as some other intoxications, but, as previously stated, the duration of morbidity of a patient must be a consideration.

Other Intoxications:

There has been little written about other acute intoxications except for those that lead to renal failure through renal cell damage.

It would seem logical that with the "flavored aspirin era" there would be a concurrent increase in the incidence of acute salycylate intoxication. With this increased incidence an increase in the severity might occur and therefore an indication for treatment of this entity by dialysis. Certainly medical management of these cases is the first step, but in the severely poisoned individual or the difficult to manage individual this treatment is indicated. It has also been our impression that in many of these cases the degree of morbidity is out of proportion to the serum level of the salicylate; similiarly the reverse may be true. Schriner(22) discusses dialysis in his article entitled "Specific Therapy for Salicylism." He reports on two cases that were treated with dialysis with very good results. Krasnoff(23) reports that as little as two grams of aspirin have caused death and the usual lethal dose is thought to be in excess of 10 grams.(24) Deaths from as small amounts as 0.3 grams must be considered to be hypersensitivity reactions but this has been reported.[(25)]

In the past few years the ataractics have also become a familiar household item, and certainly with this comes the possibility that accidental if not planned intoxication may result. In this case even less is known about the physical chemistry of these drugs in vivo. It then also becomes apparent that in any such case, a trial of dialysis would give much needed information and perhaps be life saving or at least be an important factor in decreasing the morbidity of the patient. Recently an affiliated hospital treated such an intoxication (thorazine) that had been ingested in a suicide attempt. Artificial respiration was required for several days and the patient was morbund for many more.

In closing the discussion of intoxication, I would say that any intoxication wherein it is known that the intoxication drug cannot be recovered by more conventional means, a dialysis is indicated. We believe that the procedure in innocuous to the extent that a trial is in order even though the agents physical chemical properties are not definitely known, for more often than not these agents maintain a free blood level and can be recovered through dialysis. No intoxications have been treated by this group to date, but several aspirin intoxications have been considered.

c.) Edema: A consideration for dialysis:

The consideration of intractable edema has recently come into its own as an indication for dialysis. Goldner[(26)] states that "the removal of water by dialysis should be reserved for the patients with extremely intractable edema." This implies that dialysis is a useful tool in these very difficult cases, but also reflects that this means of therapy is to be used as a last resort. Again I would repeat the theme of this dissertation, that the indications for dialysis be present, but let us not wait until the situation is hopeless before summoning our reserves. Because intractable edema is a rare entity, it would seem that this indication may be seen in the acutely over-hydrated patient; i.e. acute anuria or acute congestive failure. We have found this to be a very effective means of removing excessive fluids and the real value of this therapy remains to be more exactly proven by further clinical trials and work in experimental laboratory situations.

CONTRAINDICATIONS FOR DIALYSIS

First we must keep in mind that such things as anuria or uremia are not in themselves indications for dialysis. There must exist the chemical and clinical deteriorations before this therapy be undertaken. If the cause for the renal failure be some other disease process it is not desirable to be treating a laboratory chart; that is, to be treating a patient whose renal function will not return to a level compatable with life.

Secondly, we must consider the ability of the patient to tolerate this treatment. It has been our feeling and this seems to be the generally accepted opinion by others in the field that this procedure is tolerated very well by the very young and by the very old. In our experience no deaths have occured while dialysis was in progress nor has there been a death that we can attribute to this procedure or ramifications thereof. Perhaps then the only true contraindication would be bleeding of such a nature that the fact that heparinization could not be accomplished would be obvious. Even this very serious manifestation may fall by the way side in light of a recent publication by Gordon et. al.(27) They have discussed the feasability of regional heparinization by titrating the heparine at the outflow from the patient and protamine at the inflow to the patient. At the present time such contraindications might include oozing from the G. I. tract or from intra-cranial sites. In our present regiment, protamine is given at the termination of the procedure and clotting is restored to near normal levels.

Merrill (28) (29) also states that patients with severe hypertension and especially those with acute glomerulonephritis do not do well with dialysis in that their hypertension may become more severe to the extent that convulsions may be produced. He feels that dialysis should be deferred in these cases until the chemical deterioration out-weighs this possibility. This group has not had experience with the acute hypertension of acute glomerulonephritis nor has it been our experience to see these mentioned manifestations in the chronic (renal) hypertensive patient. We have been impressed with the hypotension that can be produced with dialysis. In two cases levophed (nor-l-epinephherine) was utilized to maintain adequate circulation. In these instances these patients were on this drug prior to dialysis and with dialysis the amount of vaso-pressor necessary to maintain adequate blood pressure was increased, probably because of dialysis of the substance in question. The contraindication then is probably the "unstable vasomotor system," a "shocky patient." The patient that has been difficult to manage regarding shock is a difficult patient to dialyze and it is desirable, often, to wait if possible until their vasomotor system is better equipped to maintain adequate pressures. It has been our experience that if a patient can maintain his blood pressure before dialysis, he will be able to do so during dialysis and after the procedure.

PROBLEMS THAT ARISE WITH THE USE OF THE KOLFF COIL DIALYZER

Inherent in the use of any mechanical device are bugs, gremlins, or whatever you may choose to call them, that must be either eliminated or the worker must be aware of their existence and deal with them accordingly. I shall attempt to enumerate some of these difficulties and indicate what we have done with them.

First, a discussion of the cannulations. In most of our cases the radial artery was found to be large enough to handle the cannula, which in itself must have certain capacities in that it must be large enough to supply the amount of blood flow desired (200 cc. per minute in the adult). If this flow is not adequate there occurs almost immediately partial or complete collapse of the tubing and the cannula between the patient and the pump. This same situation may develop if the end of the cannula is either placed against the vessel wall or is sucked into this position. As to the size of this cannula, "the larger the better," but the size of the artery limits this dimension. It is usually possible to insert a #10 or #12 Bardic (30) cannula into the adult radial artery, but it is wise to prepare several smaller and several larger sizes for this purpose.

In the actual cannulation of these arteries, we found that a longitudinal incision over the artery and after proper placement of the ligitures around the artery, a longitudinal incision through the vessel wall allowed for easy cannulation and, perhaps as important, easy reconstitution of this vessel.

The venous cannulas may cause some difficulty in that it is most important that this outlet be of adequate size. If the cannula is small the outflow resistance is high and this will cause an increase in the hydrostatic pressure in the coil. In the case of overhydration, perhaps this is the desired effect, but this effect can be obtained by placing a screw clamp on the outflow tube. The increased outflow resistance is then obtained without endangering the cannula to the outflow connection. A reflection of the magnitude of this outflow resistance pressure may be obtained by placing a mannometer at the bubble catchers area. Kolff and his group ran this pressure between 60 and 90 mm. of mercury.(31) This is an arbitrary value and the amount of water removed at a specific level of pressures as is measured by this means is not definetly known. This question requires further laboratory analysis. Along this same veim, the increased outflow resistance would allow for increased blood volume of the coil proper by further distension of this area. Because this is a nearly rigid area, having little ability to expand, I do not believe that the amount of pooling is very great even under very high outflow pressures. It has been our practice to distend this membrane to some extent by either raising the outflow end or by blocking this tube for a short time, thus insuring adequate distension. These maneuvers are carried out during the priming of the machine. It has been our regime to first pass zephran (1:1000) through the machine, then flush this with six to ten liters of isotonic saline which is followed immediately by the blood matched for the occasion.

Another consideration is the rate of flow of the dialysate through the coil. This is determined by the capacity of the pumps and is said to be in the neighborhood of three to five liters per minute.(32) This flow will fluctuate considerably if the outlet to the pumps becomes coated with small particles that are inadvertently placed in the dialysate or washed out of the coil. There are placed over these inlets small meshed screens, the purpose of which is to catch any such small particles. It is therefore important that these screens be checked occasionally, for if the pumps cannot pick up the dialysate they cannot force the fluid through the coil and the clearance of the kidney is greatly diminished.

During dialysis the patients must be heparinized. We accomplished this by injecting intravenously approximately one mg. of heparin per kilogram of body weight. In addition to this, five mg. of heparin was placed in each of the cannulas as they were put into place and twenty mg. of heparin was put into each unit of blood used in the priming of the machine. With this regime the clotting time, which was followed by the five tube Lee-White method, was found to be adequate during the dialysis (as long as six hours). In some of our cases the clotting times were found to be approaching the normal limits at the termination of the procedure. If the clotting time was prolonged at termination of dialysis, protamine was given. This dosage was determined by protamine titration and used only if the clotting time was such that it was felt that it would be dangerous to allow such prolonged clotting time to persist.

Our group of cases has not included any children, but because experience has been limited in all centers I include this topic in the discussion of special problems in dialysis. Carter (32) working at the Cleveland Clinic has reported on five cases in children treated with dialysis. In their report they state that only half of the coil is used if the child weighs twenty kilograms or less. Cannulations are done in the same manner, but the inferior vena cava is cannulated via the sapheno-femoral juncture as the blood source and the return is fed back via the sapheno-femoral juncture on the opposite side. In their discussion of flow rates values of 200 to 400 ml. per minute are stated. It would seem that these values are high for any weight, for the usual adult flow is set at 200 ml. per minute. These values seem out of line if we consider that in some of their cases only half of the coil was in use. This would double the flow in using the twin coil and quaddruple the flow if only one coil was in use. In my mind it would seem logical that if half a coil is to be used then half the rate of flow should be used.

As a final consideration, I believe that once the venous cannula has been inserted, it is well to remember that this may be retained and used for venous infusions and for the collection of blood samples during the entire uremic phase. In addition it may be used for subsequent hemodialysis. This cut down can be handled the same as any other venous cut down.

As the reader can see I do not feel that the Kolff Stationary Coil Kidney is a difficult apparatus with which to become familiar nor with thich to develop proficiency in its' use; the difficult part is to predetermine its need and to prevent its use whenever possible.

DISCUSSION

There has been in use at the University Hospital and the Bishop Clarkson Memorial Hospital an artificial kidney of the Kolff Stationary Coil type.

This type of artificial kidney was realized because of the genuine interest and continuing research that Kolff maintained through the years. His first working unit was the large drum type rotating kidney that was used so extensively during World War II and the Korean War, and it is from this parent unit that the stationary coil kidney was developed.

The Stationary Coil Kidney is made up of essentially three parts. The coil, which is truly the working portion of the artificial kidney, is where the dialysis occurs. The dializing resevoir and associated pumps hold the fluid that bathes the semipermeable membrane (coil). The third component consists of the arterial pump (Sigmamotor pump) and the arterial and venous tubing and their component parts, which, as their names imply, bring the blood from the patient to the pump, to the coil, and return the blood to the patient.

This unit has been described in detail and is known to function by simple osmosis and by ultrafiltration. Because it combines these functions it is able to attain a high clearance rate and because of its unique coil construction, has a very small priming capacity of 750 cc., which in itself is a major accomplishment over its earlier predecessors.

Kolff has, through studying clearance rates in solutions of urea, established the urea clearance rate of this unit at 140 to 160 cc. per minute. He also stated that at least 4 cc. per hour per kilogram body weight of water is removed from an individual during dialysis through the functions of ultrafiltration and perhaps osmosis. The indications for dialysis have been discussed in this paper and can generally be divided into three general categories. One, uremia or renal failure; two, intoxications; and three, edematous states. In the first category the clinical or chemical deterioration are usually quite evident. It can be stated that most authorities believe that dialysis is indicated in those individuals wherein the serum potassium level has risen to 6.5 or 7 milliequivalents, the CO_2 combining power has reached the low of ten to twelve milliequivalents and/or the Blood Urea Nitrogen exceeds 200 to 300 milligrams per cent. In addition, the clinical deterioration may indicate dialysis before these chemical changes are present.

In the second case, it is generally felt that any substance that is toxic to the body and maintains a free blood level, that is, is not bound to body proteins, can be readily dialyzed. This would include such items as the barbiturates, bromides, salicylates, ataractics and many others too numerous to mention.

The third indication, intractable edema, is rare; but this condition, when present, can be a serious problem to the practicing clinician.

The contraindications are only mentioned to show that although they are limited, some do exist.

A final portion of this paper has been devoted to a discussion of the problems, and, it is our intention to present some suggestions as to the answers to these conditions. Their context is too broad to be covered here, but in general we have attempted to deal with the cannulations, the handling of the dialysate, the specific problem of dialysis in children as described by Carter, and a brief description of the method of heparinization in our cases.

CONCLUSION

There exists an artificial kidney, namely the Kolff Stationary Coil Kidney, that is small, compact, and relatively cheap. It was developed by J. W. Kolff, now at the Cleveland Clinic, who was and is the leader in this field since its origination. This kidney is the grandchild of the first rotating type kidney that was also developed by this same scientist.

A description of this unit is contained herein; its mechanical structure, and its clinical application. It is noted that this unit functions by simple osmosis and ultrafiltration, with clearances of urea stated to be 140 to 160 cc. per minute, and its ultrafiltration rate being regulated by the resistance to outflow.

The indications for dialysis are quite easily defined and generally categorized as uremic acidosis, intoxications, and intractable edema, the etiology being quite diverse. The biochemical and clinical evaluation of the patient generally quite clearly dictates the indication for dialysis. These conditions are described in detail in this discussion.

The problems that arise in dialysis are few and easily handled once the team has been established. It has been the hope of this writer that this dissertation will be of some assistance to workers that are to be using this unit at the Bishop Clarkson Memorial Hospital in the future.

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