COMPARABLE DIALYSANCE MEASUREMENT

K. W. Fritz*

An estimation of the efficiency of an artificial kidney may be done under usual clinical conditions or under standardised, and as far as possible idealised, conditions. Comparison between the results obtained by these two techniques, and the search for optimal conditions in vitro, can give useful hints for improving the efficiency in clinical use. Moreover standardisation allows a comparison between different artificial kidneys. As ideal standardised conditions are approached, an opportunity arises to test the validity of the formula of Renkin(1) which is a derivation from the first Fick law.

To examine the necessity for, and possibility of, standardisation and idealisation, we used the Moeller(2) artificial kidney. For this purpose the Moeller kidney has the advantage over other artificial kidneys (Twin coil, Alwall, some parallel flow dialysers etc.) that it employs counter-current flow in one layer and it is therefore possible to take samples from inflow and outflow of both the blood and the bath system. The bath fluid flows around the blood tube in channels, counter current to the blood flow. The tube is supported by 7 longitudinal ridges on each side. The inner cylinder and the outer, concave cylinder are very exactly adapted so that the ridges on both sides of the tube are always opposite one another. Figure 1 shows the Moeller cylinders in connection with a 300 l. tank which was used for the experiments. The inside of the tank is made from polyvinylchloride which makes it sufficiently constant in temperature. A powerful refrigerator makes it possible to cool the bath in a few hours to nearly 0°C. The bath fluid pump has a capacity of 44 l./min. Part of it is used to provide a sufficient flow through the cylinders - up to 12 or even 16 l./min. The rest serves to mix the bath fluid.

Most papers dealing with dialysance studies concerning single factors do not state how other influencing factors were eliminated. The following conditions proved in our experience to be necessary to test single factors and to compare different dialysers.

1. No recirculation of fluids.
2. Soaking of cellophane at least 2 hours (40°C).
3. Test substance urea in aqueous solution (200-300 mg.%).
4. Bath fluid the same osmolality as the urea solution.
5. Bath fluid consisting of sodium chloride solution.
6. Equal hydrostatic pressure in both systems (inflow and outflow).
7. Temperature 40°C. in both systems.
8. 'Sufficient' mixing or speed of bath fluid.
9. Taking samples after at least double transit time.

In our experience it proved to be necessary to do dialysance measurements only without recirculation of both fluids to get reproducible conditions and to have a steady state as an important prerequisite for all formulas dealing with dialysance.

* Medizinische Universitätsklinik, Bonn.
2. The cellophane should be soaked for 2 hours at 40°C. The increase in permeability with longer soaking is negligible if the soaking is carried out at 40°C.

3. Urea should be used as the test substance because it is most frequently used and can be easily and accurately measured (particularly with the Technicon Autoanalyser). The aqueous solution should not contain other substances at the same time; for relative dialysance studies pure solutions of the different substances should always be used. This is especially important for electrolytes. Figure 3 shows how different anions influence the dialysance of the cations. Together with the small and fast-dialysing anion chloride the dialysances of the cations potassium and sodium are higher than with the bigger and more slowly dialysing anion bicarbonate, since neither cations nor anions can pass the membrane alone. In this example the potassium content was relatively high (150 mEq./l.) compared with a sodium content of 12 mEq./l. In the previous figure the relationship was reversed. Under the conditions shown in Figure 3 the potassium dialysance becomes much higher than before, as does the chloride, but the sodium dialysance decreases. These changes depend not only on the individual ions present but also on their concentrations.

4. Like hydrostatic pressure, osmotic pressure must be taken into account, since it produces osmotic ultrafiltration which is superimposed on dialysis. Without any osmotic substance in the bath fluid the dialysance becomes too high. Therefore the osmotic pressure should be the same in blood and bath fluid.

5. Osmolality should be equal not only in the inflowing fluids but also throughout the length of the cellophane tube. Therefore it is preferable to choose a solute for the bath fluid with nearly the same relative dialysance as urea. Such a substance is sodium chloride. In order to keep errors due to osmolar differences negligible it is better not to use too high concentrations of solute. Figure 4 shows the dialysance under the named conditions for the cylinders of the Moeller kidney. The bath fluid is a solution of sodium chloride with the same osmolality (35 mOsm./l.) as the urea solution in the blood pathway. The curve follows very closely the calculated curve according to formula of Renkin. The value of 'PS' for this formula was taken as the average of the PS values calculated from every measurement of dialysance. These individual measurements are shown as white dots. The black dots show dialysance estimations under the same conditions as before but with pure water as bath fluid. The values found are higher than those with sodium chloride solution.

6. The hydrostatic pressure should be as far as possible the same in the inflow of the blood system and the bath system and also in the outflow of both systems to avoid pressure gradients. The absolute height of the pressure had no influence on the dialysance in the tested range up to 300 mm. Hg. Equalisation of pressures can be achieved in the Moeller kidney but not, for example, in the twin coil kidney under normal running conditions.

7. A temperature of 40°C. was chosen for both systems because this is, in our experience, the highest temperature for clinical conditions without side effects for the patients. On the other hand temperature should be
as high as possible since it has an important influence on dialysance in this range, as Figure 5 shows. The blood flow rate was 150 ml./min. in these experiments.

8. One of the most important conditions assumed in the formula of Renkin is sufficiently rapid circulation of bath fluid over the cellophane. Figure 6 shows the influence of the flow rate of the bath fluid in the Moeller kidney at a 'blood' flow rate of 150 ml./min. For dialysance studies bath fluid flow rates should be sufficiently fast that they correspond to the almost horizontal part of the curve. With our apparatus we used 12 l./min. since with higher flow rates the pressure in the bath system became too high. Until these studies were carried out we used a bath fluid flow rate of 4 l./min. as is generally done with the weaker original pump of this artificial kidney. Figure 7 shows the increase of efficiency with a stronger pump. The points are dialysance measurements under the same conditions as before but with the lower bath flow rate. The theoretical curve is the same as in Figure 4.

It is also possible to calculate the influence of limited bath fluid flow rates instead of an infinite one, as assumed for the formula of Renkin. The relationship of the two currents, however, has to be considered. Lichtenberg(3) has extended the equation for us with regard to a counter-current system like the Moeller kidney. The Renkin formula

\[ D = a(1 - e^{-PS/a}) \]

thus becomes:

\[ D = \frac{1 - e^{-PS/a(1 - a/b)}}{1 - \frac{a}{b} e^{-PS/a(1 - a/b)}} \]

where \( b \) is the flow rate of bath fluid running counter current to the blood flow. That this new equation is a generalisation of the formula of Renkin can be seen if it is stated that \( \lim b = \infty \)

Figure 8 shows that the difference between the curve calculated from the formula of Renkin (upper one) and from the extended formula (lower one) is small under the conditions employed in this study - bath fluid flow rate of 12 l./min. and limit of the curve about 200.

In our opinion it would be valuable if such or similar standard conditions for dialysance estimations were universally employed so that observations on different machines were comparable. A comparison of the Moeller kidney and the twin coil kidney under these standardised conditions showed that the latter is a little more effective. The dialysance limit is equal to 'PS' for the formula of Renkin (according to the rule of Bernoulli-L'Hospital). For the Moeller kidney it is 183 ml./min. and for the twin coil kidney 206 ml./min.

REFERENCES

3. Lichtenberg,H. Personal communication.
Figure 1. Cylinders of the Moeller-kidney with a 300 l tank.

Figure 2. Influence of different anions on dialysance of kations.

Figure 3. Influence of electrolyte relations on relative dialysance.

Figure 4. Dialysance of the Moeller-kidney.
Figure 5. Influence of temperature on dialysance in the Moeller-kidney. (blood flow 150 ml./min.).

Figure 6. Influence of bath fluid flow on dialysance in the Moeller-kidney. (blood flow 150 ml./min.).

Figure 7. Dialysance of the Moeller-kidney with bath flow rates of 4 l./min. and 12 l./min.

Figure 8. Difference between the curves after the formula of Renkin and after the extended formula for the used conditions.