

Haemodialysis — what have we learnt in the past three decades?

Complete this course
and earn
1 CME POINT



Dr. HO Chung Ping
MBBS, MRCP, FRCP (Glas, Edin),
FHKCP, FHKAM (medicine),
Specialist in Nephrology



Ms. AU Yim Fong
Manager of the Integrated Dialysis
Facilities (HK) Ltd.

History of Haemodialysis in Hong Kong

Haemodialysis was first introduced to Hong Kong in the 1960's at the Queen Mary Hospital's 'Renal Laboratory' in ward C5. The renal unit in the Princess Margaret Hospital (PMH) was operational in the late 1970's and was the major renal centre on Kowloon side. The author was fortunate enough to witness its development since infancy and it is interesting to recount what we have learnt over the past three decades.

The principle of haemodialysis is simple: take the blood out of the patient, pass through a dialyser and return the blood to the patient after cleansing. The most difficult part is the vascular access, ie, how to take blood out of the patient at a rate of 200–300 mL/minute.

Vascular Access

In the early days, vascular access was obtained by a Scribner's shunt (the arterio-venous shunt, or AV shunt). This involved cannulation of the radial artery and the cephalic vein at the wrist with plastic cannulae and joining them together (Figure 1). During dialysis, the two cannulae were connected to the dialyser. The life span of the shunt was short as it was prone to clotting and infection (Figure 2).



Figure 1. A model of an AV shunt for staff training. It was affectionately called 'Dr Leong's hand' because (as legend has it) the original model was built by Dr C H Leong.



Figure 2. An infected AV shunt.

The AV shunt was later replaced by the AV fistula. A fistula is created by surgically joining the radial artery and cephalic vein at the wrist. Since the cephalic vein is directly fed by the radial artery, the blood flow is greater and a blood flow of 300 mL/minute can be obtained by cannulation of the arterialisised cephalic vein.

An AV fistula has a life span of many years. It does not significantly affect the lifestyle of the patient and there is no interference with bathing and swimming. It is the gold standard against which all other forms of vascular access are compared.

A fistula typically takes 4–6 weeks to thicken the vein sufficiently to take repeated needle puncture ('mature') and hence temporary vascular access is needed during the 'holding' period. In the early days, an AV shunt was created in the contralateral arm for temporary vascular access. When the fistula was functional, the AV shunt was removed. The disadvantage with this strategy was that the patient would have the blood vessels destroyed in the AV shunt arm.

To preserve the forearm veins, the team at PMH used to place the AV shunt in the ankle of the patient, so that the vessels in both wrists could be used for fistula creation in the future. However, this resulted in the patient having to walk with crutches (Figure 3).

AV shunts were replaced with venous catheters in the late 1980's. In fact, younger renal staff might not



Figure 3. An AV shunt in the ankle, a popular procedure with the PMH team.

have seen an AV shunt. Temporary vascular access is now made by cannulation of the great veins, such as the femoral vein, internal jugular vein or subclavian vein. The main advantages are the simplicity in its placement, it can be used immediately after insertion and the vessels in the forearm are spared. Infection of the femoral venous catheter is common because of the anatomical location of the vein. The subclavian venous catheter is most comfortable for the patient but a significant percentage of these patients develop arm oedema due to subclavian venous stenosis later on. The internal jugular



Figure 4a. A 'standard' internal jugular catheter.



Figure 4b. A catheter with curved limbs provides improved patient comfort.



Figure 5. A Tenckhoff's catheter inserted into great veins to be used as a haemodialysis catheter.

catheter is less comfortable to the patient but the chance of developing subclavian venous stenosis is smaller. By using a catheter with curved limbs, patient comfort can be improved (Figures 4a & 4b).

Complications of the internal jugular vein and the subclavian veins include accidental puncture of the neighbouring arteries causing haematoma, which can be fatal. In recent years, such cannulation is usually done under ultrasound guide in an X-ray suite. If there is problem during the negotiation of the guide wire, manipulation can be greatly assisted by X-ray screening.

There have been attempts to improve the life-span of the catheters, usually by adding a subcutaneous tunnel (modelled after the Tenckhoff's catheter for peritoneal dialysis). The author used a Tenckhoff's catheter (intended for peritoneal dialysis) inserted into the internal jugular vein with a subcutaneous tunnel for vascular access in 1983. The blood flow was very good but open surgery was needed (Figure 5).

In the 1990's, new tunnelled catheters came onto the market which could be introduced percutaneously (Figure 6). They were variously named 'Perm-cath' or 'RetrO' catheters. Despite the names, these catheters still had problems such as infection and clotting, hence they could not be used for long term dialysis.



Figure 6. Insertion of tunnelled haemodialysis catheter using ultrasound and X-ray screening.



Figure 7. Haemodialysis in PMH with Cobe Centry 1 machines.

Dialysers

The early dialysers used in Hong Kong were ‘parallel plate dialysers’ (‘Mini-D’). The dialysis nurses needed to build dialysers with cuprophane sheets and test for leakage before use. The procedure took quite a lot of nursing time.

Later, disposable dialysers came onto the market (the Cobe PPD-1.3 dialysers) which were factory made and ready to use. Although it was expensive, it could be reused and the cost for each dialysis was comparable to ‘self-built’ dialysers. It spared much nursing time and the chance of infection and pyrogenic reaction was much lower.

The parallel plate configuration was not the best design. A new dialyser design called ‘hollow fibre’ is shown to be much more superior. The blood, instead of flowing in between parallel membranes, is forced to flow through 7000 hollow fibres. Since the blood velocity inside the hollow fibres is high, the efficiency of the dialyser is much improved.

The cuprophane membrane used was made from plant cellulose and had its limitations, such as the small pore size and low biocompatibility. To overcome this, synthetic materials such as polysulphone are now used to make the dialysis membrane. It has much greater efficiency and since it is more biocompatible, patient tolerance is improved. Initially it was very expensive but recently the price has gone down considerably.

Haemodialysis Machines

The Cobe Centry 1 haemodialysis machines were used when the renal unit in PMH opened (Figure 7). The main function of the haemodialysis machine was to make the dialysate from dialysate concentrate and deliver it to the dialyser. One had to add the blood pump, heparin pump, etc as external components.

The machines were later replaced with the Centry

2 model in which the blood pump and heparin pump were built in. It was robust and reliable. It was phased out in the late 1990’s but the author has donated two such machines to the Hong Kong Museum of Medical Science (in good working condition!).

One drawback of the Centry 2 machine was that it could only produce dialysate using acetate as the buffer. The acetate went into the patient’s blood stream and was metabolically converted to bicarbonate. For elderly patients, the rate of bicarbonate conversion may not be fast enough and acetate accumulation caused nausea, vomiting and hypotension.

Acetate was used instead of bicarbonate was because acetate had a higher solubility in the concentrate. Bicarbonate solutions were unstable and tended to precipitate with calcium salts.

In the 1990’s, haemodialysis machines that could produce dialysate with bicarbonate were available. This was achieved by having two pumps, one to prepare a bicarbonate solution and another solution containing the rest of the ingredients. The two solutions were mixed inside the machine and delivered to the dialyser. Since both solutions were made separately, there was no calcium salt accumulation (Figure 8). Patients felt much better on bicarbonate dialysis.

Excessive fluid in the patient was removed by applying a negative pressure on the dialysate part to draw water from the blood. In the early days, nephrologists had to determinate the ‘negative pressure’



Figure 8. Bicarbonate dialysis — note the sodium bicarbonate solution and the acid concentrate bottle.

required. Newer haemodialysis machines have the ability to control and monitor the rate of fluid removal ('ultrafiltration') volumetrically. This contributes greatly to patient safety.

Since dialysis removes toxins by diffusion, small molecules (urea, creatinine, hydrogen ions) are removed more easily than larger size ('middle molecule') toxins. Our own kidneys remove toxins by filtration and all molecular species are removed. To mimic the native kidney, a 'haemofilter' with a porous synthetic membrane was used. Plasma water, together with the toxins, was removed by ultrafiltration and the volume deficit was replaced with substitution fluid.

Modern machines can perform such 'haemofiltration' together with conventional dialysis (haemodiafiltration, HDF). The substitution fluid is produced by the machine 'online' to reduce the cost. The patients feel much better on this mode of therapy (Figure 9).

Other advanced features include the option of changing the dialysate sodium concentration and 'ultrafiltration profiling', but in general the benefit is not consistently shown.



Figure 9. Haemodiafiltration (HDF) with modern haemodialysis machines.

The Treatment of Renal Anaemia

Haemodialysis can only partially replace the excretory function of native kidneys and cannot improve the renal erythropoietin production. Patients with end-stage renal failure (ESRD) are usually anaemic with haemoglobin around 7–8 g/dL or lower. Patients had to be transfused with haemoglobin when levels dropped. Repeated blood transfusion carried the risk of blood borne infection and some patients contracted 'non-A non-B hepatitis' as a result. Before the discovery of hepatitis C, there was no test for the virus.

Human recombinant erythropoietin revolutionized the management of renal anaemia. With weekly or twice weekly injections of erythropoietin, the patients' haemoglobin can be increased to around 11 g/dL. Patients felt much better subjectively, with increased exercise tolerance and improved appetite. This prevents the development of left ventricular hypertrophy, which is a risk factor for cardiovascular event.

Kt/V Story

There had been attempts to quantify the 'dose' of each dialysis session. Gotch and Sargent, on analysing the data from the National Cooperative Dialysis Study in America, proposed the Kt/V concept, where;

K = urea clearance of the dialyser
t = duration of dialysis
V = volume of distribution of urea

The concept was simple and the author now will not go into the mathematical derivation. Since the exact uraemic toxin was not known, blood urea was used as a surrogate marker. Obviously the 'dose' delivered depends on the efficiency ('clearance') of the dialyser, the duration of the dialysis and the volume of distribution of urea.

It was shown that if the Kt/V (dose) was less than 1, then the patient mortality was high. For this reason, the US National Kidney Foundation suggested a target of 1.3.

Another way of expressing the dialysis dose is the Urea Reduction Ratio (URR) where;

$$\text{URR} = \frac{(\text{pre-dialysis urea} - \text{post-dialysis urea})}{\text{pre-dialysis urea}}$$

The URR and the Kt/V are inter-related mathematically. It has been shown that the patient's survival is better if the URR is at least 60 percent. For this reason, most centres aim to achieve a minimum URR of 65 percent.

With the target Kt/V defined, some centres tried to achieve the target in a short period of time. This could be done by increasing the dialyser urea clearance by increasing the blood flow, the dialysate flow and the dialyser efficiency. Such short dialysis was common in America since a centre could perform an additional shift with short hour dialysis.

The result of the short hour dialysis was not good despite good Kt/V. One explanation was that Kt/V only takes into account the 'small molecule' clearance. With short hour dialysis, some uraemic toxins in the 'middle molecule' range were not removed adequately.

In 2002, Scribner and Oreopoulos proposed the 'haemodialysis product' HDP¹ where;

$$\text{HDP} = t \times f^2$$

t = duration of dialysis in hours

F = frequency of dialysis per week

The HDP highlights the importance of the frequency of dialysis as the most important factor in the dialysis dose since the frequency is 'squared'. Although HDP was not widely adopted, its concept was well taken. Four times per week dialysis is much better than three times per week. However, it is not possible to expand hospital haemodialysis to accommodate four dialyses weekly due to financial constrain, and home haemodialysis has again received attention.

Home haemodialysis is not new. It was popular in Hong Kong in the 1980's because of the shortage of hospital dialysis facilities. PMH ran a very successful haemodialysis program². Patients bought a machine and had the dialysis at home. However, since home haemodialysis needed a family member as a helper, it might have caused reduced family earning and was losing popularity to continuous ambulatory peritoneal dialysis (CAPD).

The comeback in home haemodialysis is assisted by new machines which are much more robust with reliable monitors and alarms. The patient can put himself on the machine and sleep while the dialysis is performed. In this way, patients can have 6 dialyses per week at home without much interference with the lifestyle. The data on such nocturnal dialysis is limited but very encouraging.

The Hong Kong Renal Patient Registry

The treatment of ESRD patients consumes a significant portion of the medical budget and it is vital to collect epidemiological and clinical data of ESRD patients for planning and research purposes. In 1986, the author pooled the data in all public hospitals and published a combined report of ESRD patients in Hong Kong³. After the formation of the Hospital Authority (HA), the Hong Kong Renal Patient registry was set up to collect and publish the ESRD patient data. This is a valuable source of data. It would be more complete if the data from private hospital patients is also included.

Satellite Haemodialysis Centres

Because of the expenses, the majority of ESRD patients in Hong Kong seek treatment in HA hospitals and are often offered CAPD as the treatment of first choice. Certain CAPD patients will need to be switched to haemodialysis due to technical or peritoneal membrane failure. With an increasing CAPD population, the requirement for haemodialysis support also increases.

The cost of hospital haemodialysis is high but it is possible to build dialysis centres outside the hospital setting with much reduced operation costs. Such renal centres are called 'Satellite Dialysis Centres'. In 1978 the Hong Kong Kidney Foundation started the first satellite dialysis in Kowloon City. The advantages of a satellite centre include:

- Location is usually more accessible than hospitals
- Much lower cost compared with hospital dialysis
- No need for helpers as in home haemodialysis
- No 'acute cases', patient pool more stable, better patient staff relationship.

The author also operates a satellite centre next to his clinic and has shown that satellite centre haemodialysis at an affordable cost in a private setting is feasible.

Conclusion

There have been many improvements in haemodialysis in the past decades in almost all areas. The greatest advance was not in the 'high-tech area' such as new dialysis machines, but in the understanding of the renal disease itself.

1. Careful attention to the patients' medical condition is the key for the success. Since most patients died from cardiovascular events and stroke, early correction of hypertension and anaemia was most important. In recent years, the control of hyper-phosphataemia and secondary hyper-parathyroidism has been receiving increasing attention.

2. "Fistula first"— the AV fistula provides the best long term access with minimal complications. Always consider the AV fistula as the access of first choice. Venous catheters entail risk of infection. To avoid complications, catheter placement should preferably be guided by ultrasound.
3. Frequency of dialysis is much more important than the dialyser clearance.
4. Hong Kong has the highest percentage of CAPD patients. Satellite Dialysis Centres provide affordable haemodialysis and is a viable option.

Haemodialysis in Hong Kong has improved greatly over the past three decades; its legend will go on.

Declaration of Interest

Dr HO Chung Ping is the medical director of the Integrated Dialysis Facilities Ltd.

References

1. Scribner BH, Oreopoulos DG. The Haemodialysis Product (HDP): A Better Index of Dialysis Adequacy than Kt/V. *Dialysis and Transplantation* 2002;31(1):13–5.
2. Ho CP. Home Haemodialysis: A Practical Mode of Therapy in Hong Kong. *The Hong Kong Practitioner* 1986;8:9.
3. Ho CP, Wong KK. A Combined Report on End-stage Renal Failure in Hong Kong. *Journal of the Hong Kong Medical Association* 1986.

Q&A

Answer these on page 16 or
make an online submission at:
www.hkmacme.org

Please indicate whether the following questions are true or false

1. Haemodialysis was first introduced to Hong Kong in the 1960's at the Queen Mary Hospital's 'Renal Laboratory' in ward C5.
2. The life span of the AV shunt was short as it was prone to clotting and infection.
3. In the 1990's, new tunnelled catheters came onto the market which could be introduced percutaneously and did not cause problems such as infection and clotting.
4. A new dialyser design called parallel plate configuration is shown to be much more superior than the 'hollow fibre' design.
5. Newer haemodialysis machines still do not have the ability to control and monitor the rate of fluid removal ('ultrafiltration') volumetrically.
6. Haemodialysis can only partially replace the excretory function of native kidneys and cannot improve the renal erythropoietin production.
7. The K/tV concept requires the urea clearance of the dialyser, the duration of dialysis and the volume of distribution of urea.
8. Home haemodialysis is losing popularity these days.
9. The cost of hospital haemodialysis is high but it is possible to build dialysis centres outside the hospital setting with much reduced operation costs.
10. Hong Kong has the highest percentage of CAPD patients.

ANSWERS TO May 2008

Whiplash Associated Disorders — Myths & Controversies – Part 3

- | | | | | |
|----------|----------|----------|---------|----------|
| 1. True | 2. False | 3. True | 4. True | 5. False |
| 6. False | 7. False | 8. False | 9. True | 10. True |

Symposium on Post-traumatic Stress Disorder (PTSD)

PTSD is a condition not easily mastered by general practitioners. It may occur in victims of the earthquake in Sichuan. To facilitate doctors to understand the condition and help volunteer doctors who are going to help the earthquake victims at Sichuan, the Hong Kong Medical Association is co-organizing a lecture on "Managing Post-traumatic Stress Disorder: The Right Way, The Wrong Way" by Professor Joseph ZOHAR in the afternoon of 19 June 2008 at Hotel Miramar Hong Kong. The lecture is coorganized by the Hong Kong Society of Biological Psychiatry and will be chaired by Professor Siu Wa TANG. Sponsored by Lundbeck Hong Kong, seats are allocated on a first come first served basis.

For details and registration, please contact
Ms. Jaclyn LEE at 2827 1988 or Janet HO at 2827 2293



Hong Kong Medical Association

