Corso Avanzato di Nefrologia Interventistica
La tecnologia al servizio della programmazione, creazione e gestione dell’accesso vascolare per emodialisi

Roma, 28-29 Maggio 2018

L’emodialisi
Carlo Lomonte
Haemodialysis is an extracorporeal blood cleansing technique that is used to remove metabolic waste products that accumulate in patients with ESRD.

Solute and water are removed through *semipermeable membranes* using different mass separation mechanisms (*diffusion, convection and adsorption*).
La dialisi non è una lavatrice
Modern hemodialysis therapy started on March 17, 1943, when Willem Kolff, a young Dutch physician in the small hospital of Kampen (the Netherlands), treated a 29-year-old woman suffering from malignant hypertension and “contracted kidneys.”
1960

Dializzatore di Kiil

Kiil 型人工腎による血液透析の研究
—過去2年間の経験と透析液の検討—

広島大学医学部泌尿器科学教室（主任：仁平寛己教授）
福重 隆、田中 広治、田戸 治,
松本 祐、仁平 寛己

HEMODIALYSIS WITH KIIL-TYPE ARTIFICIAL KIDNEY
—TWO YEARS EXPERIENCE AND STUDY ON DIALYSATE—

Mitsuru Fukushi, Hiromi Tanaka, Osamu Tado, Satoru Matsuki and Hiromi Nihira

From the Department of Urology, Hiroshima University School of Medicine
(Chairman : Prof. H. Nihira, M. D.)
For efficient intermittent haemodialysis the artificial kidney should have a low priming volume and preferably should be able to be operated without a blood pump. The countercurrent dialyser developed by Kiil (1960) and its subsequent modification (Cole et al., 1962, 1963) fulfilled these requirements. These dialysers, however, take a considerable time to prepare and need trained staff, not always readily available, to dismantle, clean, reassemble, and test each machine.

1960: Scribner-Quinton Shunt
1966: Cimino-Brescia AVF

Chronic hemodialysis using venipuncture and a surgically created arteriovenous fistula

<table>
<thead>
<tr>
<th>Component</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialyzer</td>
<td><strong>Configuration</strong> Hollow-fiber dialyzers are preferred owing to improved safety.</td>
</tr>
<tr>
<td></td>
<td><strong>Membrane biomaterials</strong> Synthetic membranes are used more frequently than cellulose membranes owing to fewer blood–membrane interactions.</td>
</tr>
<tr>
<td></td>
<td><strong>Membrane permeability</strong> High-flux membranes are constructed with larger pores, which allow greater removal of higher-molecular-weight solutes, with similar removal of lower-molecular-weight solutes as compared with low-flux membranes.</td>
</tr>
<tr>
<td></td>
<td><strong>Treatment time</strong> Usual treatment time is about 4 hours. Longer treatment times allow more fluid removal with less risk of intradialytic hypotension, and the removal of compartmentalized solutes such as phosphate is increased; nevertheless, increased dialysis time has limited effects on removal of many solutes because of decreasing plasma concentrations.</td>
</tr>
<tr>
<td></td>
<td><strong>Treatment frequency</strong> Usual frequency is 3 times per week. Increasing the frequency of dialysis to &gt;3 times per week improves solute clearance and fluid removal; effects on clinical outcomes and quality of life are being evaluated in randomized trials.</td>
</tr>
<tr>
<td></td>
<td><strong>Blood flow rate</strong> Usual prescription is 200 to 400 ml per minute. Achievable blood flow depends on the type and quality of vascular access. Increasing blood flow increases solute removal; however, increased flow resistance will eventually limit the augmented clearance.</td>
</tr>
<tr>
<td></td>
<td><strong>Dialysate flow rate</strong> Usual rate is twice the achieved blood flow rate in order to attain near-maximal solute clearance.</td>
</tr>
<tr>
<td></td>
<td><strong>Ultrafiltration rate</strong> Should be less than 10 ml per kilogram of body weight per hour to reduce the risk of intradialytic hypotension.</td>
</tr>
<tr>
<td></td>
<td><strong>Dialysate composition</strong></td>
</tr>
<tr>
<td>Sodium</td>
<td>Between 130 and 145 mmol per liter. Higher sodium concentrations decrease the risk of intradialytic hypotension but increase thirst and interdialytic weight gain.</td>
</tr>
<tr>
<td>Potassium</td>
<td>Generally 2 to 3 mmol per liter. Lower levels of dialysate potassium are associated with sudden cardiac death; intradialytic potassium removal is highly variable, and plasma potassium levels rebound about 30% after dialysis.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Generally 1.25 to 1.75 mmol per liter. Only non–protein-bound calcium is removed; higher levels of dialysate calcium increase intradialytic blood pressure.</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Generally 0.5 mmol per liter. The optimal level of magnesium is unresolved, and magnesium flux is difficult to predict.</td>
</tr>
<tr>
<td>Alkaline buffers</td>
<td>Commonly 30 to 40 mmol per liter. Predominantly bicarbonate with a small amount of acetate; bicarbonate concentration can be adjusted to correct metabolic acidosis.</td>
</tr>
<tr>
<td>Chloride</td>
<td>Defined by prescribed cations and alkaline buffers in dialysate.</td>
</tr>
<tr>
<td>Glucose</td>
<td>Commonly 100 to 200 mg per deciliter. Higher levels of glucose promote hypertriglyceridemia.</td>
</tr>
<tr>
<td>Intradialytic medications</td>
<td>Erythropoietin, iron, vitamin D analogues, antibiotics.</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>Heparin or other agents.</td>
</tr>
<tr>
<td>Variable</td>
<td>Goals and Targets</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dialysis dose</td>
<td>Monitor urea kinetic modeling; target single-pool $\text{Kt}/\text{V}_{\text{urea}}&gt;1.4$.†</td>
</tr>
<tr>
<td>Fluid management and estimated body weight</td>
<td>Carry out individualized management and assessment; interdialytic weight gain should ideally be less than 5% of total body weight.</td>
</tr>
<tr>
<td>Dialysate quality</td>
<td>Monitor endotoxin and bacteria concentrations in water used for dialysate; the use of ultrapure dialysate may reduce inflammation.⁴⁹</td>
</tr>
<tr>
<td>Anemia</td>
<td>Try to attain a hemoglobin level of 10 to 12 g per deciliter (although current recommendations may change on the basis of results from clinical trials involving patients with chronic kidney disease⁵⁰-⁵³); avoid high-dose erythropoietin; evaluate patients with erythropoietin resistance for inflammation and iron deficiency; monitor iron levels and treat iron deficiency; the long-term safety and efficacy of iron administration in patients with high ferritin levels have not been well established.⁵⁴†‡</td>
</tr>
<tr>
<td>Vascular access</td>
<td>Implement strategies to increase the placement and use of fistulas and eliminate catheter use whenever feasible⁵⁵; monitor to detect possible access dysfunction.†§</td>
</tr>
<tr>
<td>Bone and mineral disorders</td>
<td>Aim for a serum calcium level of 8.4 to 9.5 mg per deciliter and a serum phosphate level of 3.5 to 5.5 mg per deciliter; monitor serum levels of intact PTH; although the optimal target PTH level has not been well defined, maintain PTH level at &gt;2 times the upper limit of the normal range to minimize risk of low bone turnover; suppress rising PTH levels with vitamin D analogues, calcimetics, and phosphate binders.¶</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Aim for serum albumin level &gt;4.0 g per deciliter; consider enteral supplementation for progressive signs of protein energy wasting; refer patient to dietitian for nutritional counseling; restrict phosphorus, sodium, and potassium intake, as guided by laboratory studies.†</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Optimal targets and management strategies have not been well defined.⁵⁷</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>Aim for LDL cholesterol level of &lt;100 mg per deciliter; the relationship between LDL cholesterol and cardiovascular risk is confounded by inflammation; statins are without proven benefit.⁵⁸-⁶⁰</td>
</tr>
<tr>
<td>Diabetes management</td>
<td>Balance benefits of tighter glycemic control, which carries an increased risk of hypoglycemia, by means of individualized therapy; glycated hemoglobin targets have not been well defined⁶¹; manage other aspects of diabetes, such as peripheral vascular disease, intestinal dysmotility, and eye problems.</td>
</tr>
<tr>
<td>Transplantation referral</td>
<td>Provide education about transplantation and timely referrals for suitable candidates; monitor status of wait-listed patients.§</td>
</tr>
<tr>
<td>Quality-of-life and psychosocial evaluation</td>
<td>The evaluation, conducted by a social worker with the support of a multidisciplinary team, should be aimed at optimizing adjustment to kidney failure and its treatment; the Kidney Disease Quality of Life (KDQOL-36) instrument is often used for the evaluation.⁶</td>
</tr>
</tbody>
</table>
Haemodialysis membranes

In the past: the major distinction was between **cellulosic** and **non-cellulosic** membranes.

**Cellulosic membranes**
cuprammonium rayon-based membranes (also known as cuprophan)
cellulose acetate
cellulose triacetate

**Non-cellulosic membranes** (synthetic membranes)
polyamide, PS,
polyethersulfone,
polyarylethersulfone,
PAN,
polymethylmethacrylate.
Structural characteristics of some commercially available synthetic dialysis membranes

Scanning electron micrographs of the fibre (left), fibre wall (middle) and a magnified cross-sectional view of the internal skin layer (right). For reference, the inner diameter of the fibres is ~200 µm. Different structural features of the membranes are discernible, and the membranes have varying degrees of asymmetric configuration, ranging from minimum asymmetry (sponge-like; parts a–e) to maximum asymmetry (finger-type; parts f,g).

Ronco and Clark, Nat Rev Nephrol 2018
Ronco and Clark, Nat Rev Nephrol 2018
“expanded haemodialysis” utilize membranes designed to produce a high degree of internal filtration
Performance characteristics of HD membrane

Kuf  20-40 ml/h/mmHg/m²
SC beta2  0.7-0.8
Albumin < 0.5 g

Kuf > 40 ml/h/mmHg/m²
SC beta2  1.0
Albumin  2-6 g

Ronco and Clark, *Nat Rev Nephrol* 2018
Classification of uremic solutes by molecular weight:

- Urea (60)
- Phosphate (96)
- Creatinine (113)
- PTH (9500)
- Beta 2 microglobulin (11800)
- Cystatin C (13300)
- Myoglobin (17000)
- Kappa free light chains (22500)
- Complement factor D (24000)
- Interleukin-6 (24500)
- Alpha 1 microglobulin (33000)
- YKL-40 (40000)
- Lambda free light chains (45000)
- Albumin (67000)

- Small molecules < 500 Da
- Conventional Middle molecules 500 - 15000 Da
- Large Middle molecules > 15000 Da
- Essential proteins

Kidney:
- Low Flux
- High Flux
- HDF
- HDx
Multidimensional Classification of Dialysis Membranes

Claudio Ronco\textsuperscript{a, b} • Mauro Neri\textsuperscript{b} • Anna Lorenzin\textsuperscript{b} • Francesco Garzotto\textsuperscript{a, b} • William R. Clark\textsuperscript{c}
Key points

- Traditional schemes for the classification of dialysis membranes, based simply on composition and water permeability, are outdated and new approaches are needed.

- Dialyser utilization in clinical practice has evolved over time and is now dominated by devices with synthetic high-flux membranes.

- Rational treatment prescription by clinicians requires an understanding of the basic mechanisms underlying solute and water removal in dialysis — namely, diffusion, convection, adsorption and ultrafiltration.

- New therapies (including expanded haemodialysis) that utilize membranes designed to produce a high degree of internal filtration are undergoing clinical evaluation as potential alternatives to convective therapies, such as on-line haemodiafiltration.

Ronco and Clark, Nat Rev Nephrol 2018
Treatment time

Frequency of dialysis
Alla fine degli anni ‘60 la durata della dialisi era di 8-12 ore per 3 volte alla settimana.

Short dialysis schedules (SDS)-finally ready to become routine?

V Cambi et al, *Proc Eur Dial Transplant Assoc* 1975
a) **Convenzionale intermittente**
   
   3-5 ore, tre volte alla settimana

b) **Lunga intermittente:**
   
   > 5 ore, tre volte alla settimana

c) **Breve quotidiana:**
   
   2-3 ore, sei o sette volte alla settimana

d) **Lunga quotidiana notturna:**
   
   6-10 ore, sei o sette notti alla settimana

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**EBPG guideline on dialysis strategies**

J Tattersal et al. *Nephrol Dial Transplant* 2007;S2:ii5-ii21
### Suggested Taxonomy of Intensive Hemodialysis (HD)

#### Treatment Time

<table>
<thead>
<tr>
<th>Classification</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged/nocturnal</td>
<td>&gt;6 hours</td>
</tr>
<tr>
<td>Standard</td>
<td>3–6 hours</td>
</tr>
<tr>
<td>Short</td>
<td>&lt;3 hours</td>
</tr>
</tbody>
</table>

#### Treatment Frequency

<table>
<thead>
<tr>
<th>Classification</th>
<th>HD/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>&gt;4/week</td>
</tr>
<tr>
<td>Alternate</td>
<td>3.5 or 4/week</td>
</tr>
<tr>
<td>Standard</td>
<td>3/week</td>
</tr>
</tbody>
</table>

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"__________ - _________ HD"
Long Interdialytic Interval and Mortality among Patients Receiving Hemodialysis

Robert N. Foley, M.B., David T. Gilbertson, Ph.D., Thomas Murray, M.S., and Allan J. Collins, M.D.

ABSTRACT

BACKGROUND
Patients with end-stage renal disease exhibit metabolic and vascular changes that increase the prevalence of cardiovascular disease (CVD) and death. We hypothesized that longer interdialytic intervals in patients receiving hemodialysis would be associated with increased CVD mortality.

METHODS
We studied 32,060 patients in the U.S. Renal Data System Measures Project who began hemodialysis three days or more after the start of dialysis. We compared rates of any CVD (mostly CHF and MI), MI, stroke, and dysrhythmia in the first two days of the three-day interdialytic interval (HD1, HD2) compared with days 3-5 (HD3).

RESULTS
The mean age of our study population was 60 years. Patients with a longer interdialytic interval experienced lower rates of any CVD (6.3 vs. 3.9, P<0.001), congestive heart failure (29.9 vs. 16.9, P<0.001), stroke (4.7 vs. 3.1, P<0.001), dysrhythmia (20.9 vs. 11.0, P<0.001), and any cardiovascular event (44.2 vs. 19.7, P<0.001).
A nationally representative cohort of Canadian HHD patients from 1996-2012 was studied.

202, short daily HHD (2-3 hours/5 plus sessions per week)

508, nocturnal HHD (6-8 hours/5 plus sessions per week)

600, conventional HHD (3-6 hours/2-4 sessions per week)

…patients receiving short daily and nocturnal HHD had similar patient/treatment survival compared with patients receiving conventional HHD
In-center hemodialysis six times per week versus three times per week

Frequent hemodialysis was associated with favorable results with respect to the composite outcomes of death or change in left ventricular mass and death or change in a physical-health composite score but prompted more frequent interventions related to vascular access.

The effects of frequent nocturnal home hemodialysis: the Frequent Hemodialysis Network Nocturnal Trial.

There was a trend for increased vascular access events in the nocturnal arm. Thus, we were unable to demonstrate a definitive benefit of more frequent nocturnal hemodialysis for either coprimary outcome.

Long-term Effects of Frequent Nocturnal Hemodialysis on Mortality: The Frequent Hemodialysis Network (FHN) Nocturnal Trial.

Patients randomly assigned to nocturnal hemodialysis had a higher mortality rate than those randomly assigned to conventional dialysis.
2,086 identified citations, 21 met the inclusion criteria, comprising a total of 1,165 in-center nocturnal HD patients and 15,865 conventional HD patients.

Relative to conventional HD, in-center nocturnal HD was associated with improvements in several clinically relevant outcomes.

Wong et al, AJKD 2017
<table>
<thead>
<tr>
<th>Study Type</th>
<th>Study</th>
<th>MD (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quasi-experimental</td>
<td>Weinreich 2006</td>
<td>0.50 (-0.36, 1.36)</td>
</tr>
<tr>
<td></td>
<td>Jin 2011</td>
<td>0.10 (-0.33, 0.53)</td>
</tr>
<tr>
<td></td>
<td>Ok 2011</td>
<td>0.40 (0.20, 0.60)</td>
</tr>
<tr>
<td></td>
<td>Wald 2016</td>
<td>-0.08 (-0.56, 0.40)</td>
</tr>
<tr>
<td>Retrospective cohort</td>
<td>Powell 2009</td>
<td>0.70 (0.37, 1.03)</td>
</tr>
<tr>
<td></td>
<td>Lacson 2010</td>
<td>0.05 (-0.06, 0.16)</td>
</tr>
<tr>
<td>Prospective before-after</td>
<td>Alloatti 2002</td>
<td>1.00 (-0.10, 2.10)</td>
</tr>
<tr>
<td></td>
<td>David 2009</td>
<td>1.20 (0.71, 1.69)</td>
</tr>
<tr>
<td></td>
<td>Dal 2013</td>
<td>1.76 (1.52, 2.00)</td>
</tr>
<tr>
<td></td>
<td>Navarro 2014</td>
<td>0.00 (-0.27, 0.27)</td>
</tr>
<tr>
<td></td>
<td>Graham-Brown 2015</td>
<td>0.33 (-1.09, 1.75)</td>
</tr>
<tr>
<td>Retrospective before-after</td>
<td>Fajardo 2003</td>
<td>1.00 (0.03, 1.97)</td>
</tr>
<tr>
<td></td>
<td>Gubensker 2013</td>
<td>0.10 (-0.35, 0.55)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>0.53 (0.11, 0.94)</td>
</tr>
</tbody>
</table>
Wong et al, AJKD 2017

Panel A: Phosphate, mg/dL
- Quasi-experimental
  - Weinreich 2006: MD (-0.31, -1.69, 1.07)
  - Jin 2011: MD (-1.39, -1.96, -0.82)
  - Ok 2011: MD (-1.09, -1.24, -0.94)
  - Wald 2016: MD (-0.24, -0.75, 0.27)
- Retrospective cohort
  - Powell 2009: MD (-0.09, -0.48, 0.31)
  - Lacson 2010: MD (-0.19, -0.31, -0.07)
  - Lacson 2012: MD (0.16, -0.07, 0.39)
- Prospective before-after
  - Alloati 2002: MD (-1.20, -2.16, -0.24)
  - Davide 2009: MD (0.08, -0.13, 0.29)
  - Dal 2013: MD (-0.12, -0.95, 0.71)
  - Navarro 2014: MD (0.26, 0.15, 0.37)
  - Graham-Brown 2015: MD (-1.64, -2.86, -0.42)
- Retrospective before-after
  - Fajardo 2003: MD (-1.10, -1.98, -0.22)
  - Trojde 2007: MD (-0.90, -1.53, -0.27)
  - Cravedi 2009: MD (-0.80, -2.84, 1.24)
  - Gubensek 2013: MD (-0.02, -1.76, -0.08)
- Total: MD (-0.97, -1.48, -0.46)

Panel B: Calcium, mg/dL
- Quasi-experimental
  - Weinreich 2006: MD (-0.16, -0.77, 0.45)
  - Jin 2011: MD (1.58, 1.30, 1.86)
  - Ok 2011: MD (0.17, 0.07, 0.27)
  - Wald 2016: MD (0.20, -0.06, 0.46)
- Retrospective cohort
  - Powell 2009: MD (0.08, -0.13, 0.29)
  - Lacson 2010: MD (-0.12, -0.95, 0.71)
  - Lacson 2012: MD (0.16, -0.07, 0.39)
- Prospective before-after
  - Alloati 2002: MD (0.08, -0.13, 0.29)
  - Davide 2009: MD (-0.16, -0.78, 0.46)
  - Dal 2013: MD (-0.12, -0.95, 0.71)
  - Navarro 2014: MD (0.26, 0.15, 0.37)
- Retrospective before-after
  - Fajardo 2003: MD (-0.40, -0.19, 0.99)
  - Trojde 2007: MD (0.00, -0.45, 0.45)
  - Cravedi 2009: MD (-0.20, -1.00, 0.60)
  - Gubensek 2013: MD (0.40, -0.03, 0.83)
- Total: MD (0.40, -0.03, 0.83)

Panel C: Parathyroid hormone, pg/mL
- Quasi-experimental
  - Weinreich 2006: MD (-43.36, -193.08, 106.36)
  - Jin 2011: MD (-166.90, -283.01, -70.79)
  - Ok 2011: MD (-6.00, -47.59, 35.59)
  - Wald 2016: MD (153.83, 14.71, 292.56)
- Retrospective cohort
  - Powell 2009: MD (38.36, -96.59, 172.31)
  - Lacson 2010: MD (60.22, -22.57, 143.01)
  - Lacson 2012: MD (57.80, -74.26, 189.86)
- Prospective before-after
  - Alloati 2002: MD (-33.00, -94.07, 28.07)
  - Davide 2009: MD (38.36, -96.59, 172.31)
  - Dal 2013: MD (60.22, -22.57, 143.01)
  - Navarro 2014: MD (57.80, -74.26, 189.86)
  - Graham-Brown 2015: MD (-4.00, -120.49, 112.49)
- Retrospective before-after
  - Fajardo 2003: MD (-7.02, -72.88, 58.86)
  - Trojde 2007: MD (-24.20, -532.37, 51.97)
  - Cravedi 2009: MD (-4.00, -120.49, 112.49)
  - Gubensek 2013: MD (-7.02, -72.88, 58.86)
- Total: MD (-7.02, -72.88, 58.86)
Can the effects of increased time be separated from increased dose?

• “The role of time as an independent determinant factor of dialysis adequacy requires further study”

EBPG guideline on dialysis strategies
J Tattersal et al. Nephrol Dial Transplant 2007;S2:ii5-ii21
Impact of hemodialysis duration on the removal of uremic retention solutes

9 pazienti stabili dializzati per 4, 6 e 8 ore, stesso volume di sangue e dialisato

<table>
<thead>
<tr>
<th>Durata, ore</th>
<th>Qb/Qd, ml/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>350</td>
</tr>
<tr>
<td>6</td>
<td>250</td>
</tr>
<tr>
<td>8</td>
<td>187,5</td>
</tr>
</tbody>
</table>

S Eloot, Kidney Int 2008;73: 765,
Impact of hemodialysis duration on the removal of uremic retention solutes

Increase 4 vs 8 h: 26%, 35%, 48%, 81%

Urea kinetic modeling predicts morbidity and mortality better than kinetic modeling of any other known solute.

The general perception is that dialysis kinetic modelling is a highly abstract research topic for mathematicians, sitting somewhere in an office far from the patient’s bedside and from practical application.

Eloot, Schneditz, Vanholder, NDT 2012
Effect of the hemodialysis prescription of patient morbidity: report from the National Cooperative Dialysis Study


“patients randomized to higher time–average BUN (100 mg/dl) had worse survival than those randomized to lower BUN (50 mg/dl)”

A mechanistic analysis of the National Cooperative Dialysis Study (NCDS)


“... secondary analysis found a significantly worse survival in patients with $Kt/V < 0.9$, independently of their treatment time or BUN”
Measuring the clearance of solutes has become the mainstay for calculating the dose of dialysis and determining its adequacy as delivered.

\[ \text{Extraction ratio} = \frac{(C_{\text{in}} - C_{\text{out}})}{C_{\text{in}}} \]

Golper et al, *AJKD* 2013
Fig. 2. The classic serial two-compartment model. $V_1$, plasma volume; $V_2$, non-plasmatic volume; $V$, total distribution volume; $C_1$, plasma concentration; $C_2$, non-plasmatic concentration; $G_1$ and $G_2$, generation rate in $V_1$ and $V_2$; $E_1$ and $E_2$, metabolic elimination in $V_1$ and $V_2$; $K_R$, renal clearance; $K_{ER}$, extra renal clearance; $K_D$, dialyser clearance; $K_{12}$, intercompartment clearance.
3.1 We recommend a target single pool Kt/V (spKt/V) of 1.4 per hemodialysis session for patients treated thrice weekly, with a minimum delivered spKt/V of 1.2. (1B)
Urea kinetic modelling—are any of the 'bedside' Kt/V formulae reliable enough?

Aim: to test 'gold-standard' UKM-Kt/V with various shortcut bedside formulae

507 dialysis sessions in 50 patients

Covic et al, NDT 1998
Daugirdas 2

\[ Kt/V = - \ln \left( \frac{Ct}{C0} - 0.008t \right) + \left( 4 - 3.5 \times \frac{Ct}{C0} \right) \times \frac{Uf}{Wt} \]

Jindal

\[ Kt/V = 0.04 \left( \frac{(C0 - Ct)}{C0} \times 100 \right) - 1.2 \]

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKM</td>
<td>0.949</td>
<td>0.27</td>
</tr>
<tr>
<td>Jindal</td>
<td>1.054</td>
<td>0.35</td>
</tr>
<tr>
<td>Daugirdas 2</td>
<td>0.995</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Covic et al, *NDT* 1998
Hemodialysis Time and $Kt/V$: Less May Be Better

James Tattersall
Department of Renal Medicine, St. James’s Hospital, Leeds, United Kingdom

» Twice Weekly Dialysis
» Fluid Homeostasis
» Phophate
» Potassium
» Residual Renal Function
Summary of studies examining the association between infrequent HD and clinical outcomes

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Study Title</th>
<th>Incident HD Patients (n)</th>
<th>Hemodialysis Frequency</th>
<th>Clinical Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obi Y et al.</td>
<td>AJKD -2016</td>
<td>23,645</td>
<td>2HD/wk</td>
<td>Greater preservation of RKF. Higher mortality after the first year of dialysis in patients with the lowest RKF.</td>
</tr>
<tr>
<td>Obi Y et al.</td>
<td>JASN – 2016</td>
<td>6,538</td>
<td>2HD/wk</td>
<td>Graded association of RKF decline during the first year of dialysis with all-cause mortality</td>
</tr>
<tr>
<td>Mathew AT et al.</td>
<td>KI – 2016</td>
<td>50,756</td>
<td>2HD/wk</td>
<td>Comparable results to 3HD/wk initiation for modeled mortality risk in selected patients with adequate RKF and reasonable general health</td>
</tr>
<tr>
<td>Park JI et al.</td>
<td>NDT – 2017</td>
<td>927</td>
<td>2HD/wk</td>
<td>Comparable results to 3HD/wk initiation for health-related quality of life, RKF and all-cause mortality</td>
</tr>
</tbody>
</table>

Taken together, the majority of the available literature suggests a non-inferiority related to survival, in that there appears to be no overtly harmful effects on survival to patients by reducing dialysis dose so long as a significant RKF is present.
The current guidelines (K/DOQI and European Best Practice Guidelines) advise to achieve a total EKR (dialytic = EKRd + renal = KRU) at least equal to the adequacy value corresponding to an equilibrated Kt/V (eKt/V) of 1.2 in an anuric patient on a 3HD/wk regimen = 12 ml/min/35 L

\[ \text{total EKR} = EKRd + KRU = 12 \text{ ml/min/35 L} \]

It is the so called **Fixed Target Model** (FTM): the sum of KRU and EKRd should achieve the fixed total EKR target of 12 ml/min/35 L.
The **Variable Target Model (VTM)**, gives more clinical weight to the RKF and allows less frequent HD treatments at lower RKF as opposed to the FTM, based on the wrong concept of the clinical equivalence between KRU and dialytic clearance.
La personalizzazione della terapia emodialitica: la dialisi non è una lavatrice

Antonio Santoro

1Divisione di Nefrologia, Dialisi ed Ipertensione, Policlinico S. Orsola-Malpighi Azienda Ospedaliero-Universitaria di Bologna
Il Registro Italiano di Dialisi e Trapianto della Società Italiana di Nefrologia nel 2015 ha censito
42.375 pazienti in HD,
4.438 in PD
23.467 portatori di trapianto renale

La prevalenza è risultata di 770 per milione di abitanti,
l’incidenza era di 154 pazienti per milione di abitanti.
Circa 7 milioni di trattamenti eseguiti ogni anno in Italia,
con un impegno di spesa annua che va oltre i 2 miliardi
di euro.

Editorial

It is time for "green dialysis"

INTRODUCTION
On the great global issue of climate change . . . is it, or is it not occurring? . . . and, if it is, is human activity contributing, or is it a purely natural phenomenon? . . . there are the believers, and the non-believers.

However, science overwhelmingly supports both notions: That climate change is occurring, and that we have much to answer for as we continue to devastate our natural environment and resources in pursuit of health, wealth, and comfort.1 And, on both issues, science does now seem to have the "ear" of governments.

As a result, increasing pressure is being brought to bear on all governments—first, developing and third world alike—to increase the use of renewable resources, to reduce greenhouse gas emissions, and to better design and manage waste disposal systems, all in an effort to minimize carbon generation.

In turn, governments are now beginning to impose carbon reduction programs on their populations: A variety of carbon credit and/or trading schemes, carbon tax initiatives, and other mechanisms, in order to lessen their national carbon footprints.2 Government departments are also being increasingly "required" to submit forward environmental plans that project their contribution to the national and global whole. With this top-down process in

WHERE A NATIONAL APPROACH HAS ALREADY BEEN TAKEN

In the United Kingdom, the National Health Service has encouraged, funded, and actively supported a sustainable health care program and, within it, a Green Nephrology initiative that has changed the face of dialysis programs throughout the United Kingdom within the remarkably short time frame of 3 years since its inception in 2009/2010.3 In a recent news article in the Green Nephrology network, Frances Mortimer, the director of the Green Nephrology program in the United Kingdom, writes:4 "commenting on a Green Nephrology study into savings from green initiatives in kidney units, National Clinical Director for Kidney Care, Dr Donal O'Donoghue, said 'it is not unreasonable to expect approaching £1 billion per year saving if the enthusiasm and focused work of the kidney community spread across the whole NHS.'"5

WATER AND POWER

While it is impossible to precisely quantify the impact of dialysis on global water and power resources and there are no data—either at a global or at a national level—to inform reasonable debate, if estimates6 that there are

- Use ~156 billion L of water (discarding two-thirds as reject water).7
- Consume ~1.62 billion kWh of power.7
- Generate (~2.5 kg per treatment) ~625,000 ton of disposable waste.8

John W. M. AGAR
Geelong Hospital, Barwon Health, Geelong, Victoria, Australia
Green Dialysis: The Environmental Challenges Ahead

1. Minimize water use and wastage
2. Consider strategies to reduce power consumption and/or use alternative power options
3. Develop optimal waste management and reusable material recycling programs
4. Design smart buildings that work with and for their environment
Grazie per l’attenzione