Fluid and Solute Removal: How and Why—Part Two

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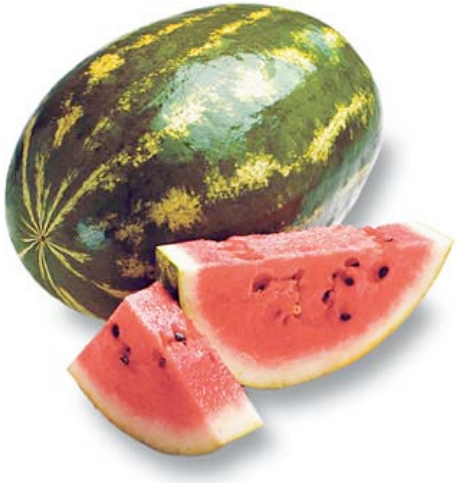
Do you know how much of your body weight is water? Like a watermelon, we *look* solid, but a lot of us—about half—is fluid. Healthy kidneys control the amount of water in our bodies, silently, without fuss, and very accurately. When the kidneys fail, dialysis can help maintain fluid balance.



With kidney disease, water (and salt) control fails, so water is retained. Fluid builds up, and you get sodden! Your ankles swell, your lungs get wet, you may feel short of breath and, most often, your blood pressure rises.

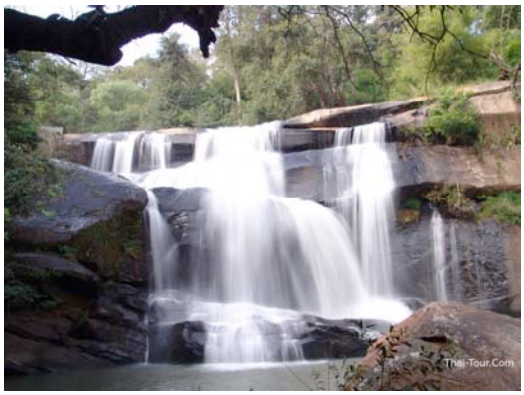
When you are on dialysis, the build-up of excess fluid is the critical (and life threatening) issue. For a while, you may still make some urine, which helps fluid balance. But, many…well, most… don't.

Fluid Shifts in the Body

It is *vital* for you to know that, like solute movement, ***fluid movement between body compartments (from cells to interstitium to blood), is rate limited too!***

Here's why: As you know (from Part 1) dialysis removes solutes and fluids only from the blood compartment. Once fluid is removed from the blood, a chain reaction starts. First, fluid "waterfalls" from the interstitium into the blood, to keep blood volume constant. This shrinks the interstitium. So, fluid then moves from inside the cells to the interstitium to keep it constant, too.

This "waterfall," of fluid moving from one compartment to another, is **rate-limited to a maximum of 350 to 400ml/hr**. It takes time for fluid to shift in your body so all is in balance. If fluid is pulled out of the blood too quickly during a standard in-center dialysis treatment, the rest of the chain reaction just can't keep up.



The result? Have you ever felt like you were run over by a steamroller after dialysis? Ever

cramped? Vomited? Needed saline? Had to sleep for hours after a treatment? These are symptoms of too much or too-rapid blood volume loss. In the long term, this strain can damage your heart.

Time-limited Fluid Shifts

How fast *can* the blood volume be replaced from the interstitium during a treatment? Well, it depends. Lots of factors make a difference:

- Your blood protein (albumin) level
- How healthy your heart is
- How big or small you are
- How "leaky" your smallest blood vessels (capillaries) are to fluid

If you assume a maximum rate of fluid removal (ultrafiltration rate or UFR) of 350 to 400ml/hour for an average sized person, you won't be far off:

- If your UFR is *less* than 400ml/hr, interstitial fluid can refill your blood as fast as dialysis removes it. So, your blood volume *won't* drop and your blood pressure will be stable.
- If your UFR is *higher* than 400 ml/hr, your interstitium can't keep up. Your blood volume *must* fall and your blood pressure will drop, too. (You'll feel awful.)

The more your UFR exceeds 400ml/hr, the greater the gap between fluid loss and refill. The greater the gap, the higher the risk of affecting your blood pressure.

Why More HD is Better

We've looked at the two main jobs of dialysis: solute & fluid removal. To understand *how* the rate of fluid removal affects the blood volume and your risk of symptoms during dialysis, look at the following two tables. In **table 1**, you can see what happens when you need to remove a *lot* of fluid in a standard 4-hour HD session. (Let's assume for this example that you don't make any urine.)

As you can see, when you have more fluid to remove, your UFR has to be set to a higher rate. But your interstitium *can't* refill any faster than 400 ml/hr at the most. At higher UFRs, *your blood volume has to drop*. This leads to a much higher chance of having unpleasant symptoms—largely because your blood pressure drops during dialysis.

Table 1

HD Time (Hrs)	Fluid gain in ml (Kg)	UFR	Rate of fluid refill from interstitium	Change in blood volume	Chance of symptoms or BP drop
4	800 ml	200 ml/hr	200 ml/hr	0	0
4	1600 ml	400 ml/hr	400 ml/hr	0	0
4	2400 ml	600 ml/hr	400 ml/hr	-200 ml/hr	Small
4	3200 ml	800 ml/hr	400 ml/hr	-400 ml/hr	Major
4	4800 ml	1200 ml/hr	400 ml/hr	-800 ml/hr	*Will happen*

Table 2

HD time (Hrs)	Fluid gain in ml (Kg)	UFR	Rate of fluid refill from interstitium	Change in blood volume	Chance of symptoms or BP drop
8	800 ml	100 ml/hr	100 ml/hr	0	0
8	1600 ml	200 ml/hr	200 ml/hr	0	0
8	2400 ml	300 ml/hr	300 ml/hr	0	0
8	3200 ml	400 ml/hr	400 ml/hr	0	0
8	4800 ml	600 ml/hr	400 ml/hr	- 200 ml/hr	Small

In **table 2**, the same amount of fluid is removed but the length of dialysis has been *doubled* (8 hours instead of 4). As you can see, now blood volume is much more stable. With a longer HD time, a lower UFR can be used—*even with much more fluid to remove*—which means fewer (or no) symptoms for you.

With longer HD, your heart and circulation are not dried out to a crisp during treatments. Cramps, vomiting, and feeling dizzy or wiped out after a treatment just *do not happen*.

Thirst and Fluid Removal

The higher your UFR is on dialysis, the more thirsty you will be, too. Taking off too much fluid, too fast, turns on your thirst drive, so you *need* to drink. This sets the scene for gaining too much fluid weight before your *next* treatment, a blood pressure surge…and so it goes on.

Longer HD treatments are much less likely to trigger thirst. Better fluid management is one reason why longer HD is better. Of course, solute removal is significantly better too—especially phosphate. Your heart, circulation, and lungs will "breathe easier" with longer HD.

How Short Daily HD Stacks Up

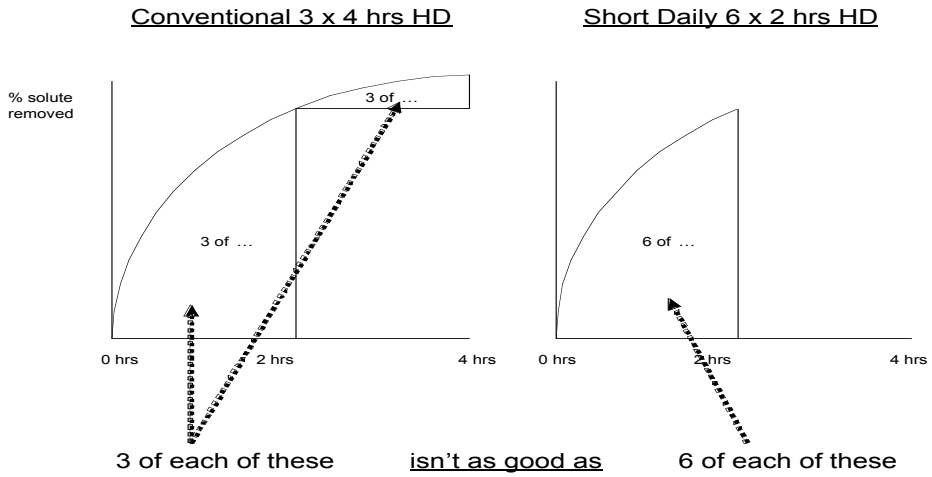
More frequent, "short daily" HD treatments used especially in the U.S. are *short* treatments (2.5-3 hours, not 3-4 hours) but done 5-6 sessions per week instead of three.

At the outset, I confess a personal struggle with this style of treatment. Solute removal is very efficient, but fluid control, by and large, does not improve—or barely so. Cutting the time in half but doubling frequency means that total fluid removal *time* does not change from standard in-center HD.

To me, this solves only half the problem—solute removal. Even then, it does *not* solve the issue of those contrary solutes, like phosphate, where time is the key.

Why is small solute removal better with short daily HD than with standard in-center HD? Solutes that diffuse rapidly across a dialyzer membrane (e.g., urea, potassium) do so fastest when their level in the blood is high. The difference

(*gradient*) between blood and dialysate is at its greatest at the start of an HD treatment. As dialysis goes on, wastes are removed and their blood levels fall. But, the rate of diffusion falls, too. The first hour of HD is the "oomphiest." The second hour is next best, etc. For small solutes, most of the action takes place in the first 1-2 hours. Repeating this period six times a week will remove solutes more efficiently.



Longer is Better

For solutes that need time, longer treatments are better. Phosphate is one such strange, slow-moving solute. It drops early, but then its removal rate flattens out to a more steady loss. Short daily HD beats standard HD—even for phosphate—since the first hour of rapid removal occurs 6 times a week. But, long HD, has much more benefit from the increase in time.

For fluid removal, short daily HD may pull up short. Though the time between HD sessions is halved vs. standard, in-center HD, the length of each treatment is *also* halved. This means half the time between sessions for fluid gain—but also half the HD time to remove it in. Mathematics says this *must* result in the same rate of fluid removal as with standard HD. Fluid intake limits are still needed.

Less Fluid Weight Gain on Daily

On the other hand, one of the main problems for your heart is the *amount of fluid* you gain from one treatment to the next. Two days between treatments (three on a weekend) means you retain two (or three) days of fluid. If you drink 2 liters a day, you will gain 3 liters between

treatments (about 1/2 liter is lost each day in sweat, breathing, and stool). This extra fluid swells the blood volume, stretches the heart, raises the blood pressure, and wets the lungs.

Since short daily HD is done *each* day, only *one* day's worth of fluid is gained…for half the stretch, half the rise, half the wetting. This is why short daily dialysis is better for fluid management than standard in-center treatments.

Nocturnal HD

In the nocturnal home HD (NHHD) —we do 8-9 hour sessions on five or more nights/week—treatment is both longer *and* more frequent. NHHD that lasts twice as long and is done up to twice as often *must* mean less fluid to remove each treatment *and* twice the time at each treatment to remove it in. NHHD is thus the gentlest option for your heart, your circulation, and your body.

Long, frequent dialysis (which, when you think about it, is only practical at home and at night) offers the best solute removal *and* the best fluid control. In my view (though some would say I am biased), it is the Rolls Royce of treatments.

What is clear is that for both solute *and* fluid control, standard HD offers the *least* benefit of all of the possible options.