Chapter (13)

Double Pool Urea Kinetic Modeling

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CHAPTER OUTLINES

• Single pool model versus double pool model.
• Mathematical analysis of double pool urea kinetic models.
• Estimation of equilibrated post-dialysis blood urea concentration.
• Estimation of post-dialysis urea rebound.
• Estimation of equilibrated dialysis dose.
• Regional blood flow model
• Conclusion

CHAPTER OBJECTIVES

• Introduce the difference between single and double pool urea kinetic models.
• Discuss the concept of urea rebound.
• Explain the mathematical analysis of double pool urea kinetic models.
• Describe the different methods of estimating equilibrated urea concentration and urea rebound.
• Describe the different methods of calculating the double pool Kt/V.
• Discuss the concept of regional blood flow models.
• Explain the mathematical analysis of regional blood flow model.

KEY TERMS

• Single pool urea kinetic models
• Double pool urea kinetic models
• Intracellular compartment
• Extracellular compartment
• Urea rebound
• Equilibrated urea concentration
• Equilibrated dialysis dose Kt/V
• Access recirculation
• Cardiopulmonary recirculation
• High-efficiency dialysis
• Regional blood flow model

ABSTRACT

Urea kinetic modelling (UKM) has been generally accepted as a method for quantifying hemodialysis (HD) treatment. During hemodialysis, reduction in the urea concentration in the intracellular fluid (ICF) compartment will lag behind that in the extra cellular fluid (ECF) compartment, and
following the end of dialysis, a "rebound" in the blood level of urea will occur where it continues to rise due to diffusion of urea from the ICF to ECF to establish an equilibrium state. Because of compartment effects, the dose of dialysis with regard to urea removal is significantly overestimated from immediate post-dialysis urea concentrations, because 30 to 60 min are required for concentration gradients to dissipate and for urea concentrations to equilibrate across body water spaces during the post-dialysis period. To avoid the delay of waiting for an equilibrated post-dialysis sample, it became necessary to describe and to quantitate effects causing the urea compartmentalization during dialysis; two-pool modeling approaches have been developed that more accurately reflect the amount of urea removed. This in turn gives more adequate measures not only of dialysis adequacy, but also of the protein catabolic rate, an important nutritional measure that is clinically monitored in dialysis patients. This chapter discusses the double pool urea kinetic models and regional blood flow models in order to understand the concept of urea rebound.

13.1 SINGLE POOL MODEL VERSUS DOUBLE POOL MODEL

A single pool model can only describe the urea kinetics correctly if the patient is in complete equilibrium. This is fairly correct within the intermediate phases of two dialyses. During dialysis this is completely incorrect because the patient from this aspect can be regarded as composed of two fractional urea distribution volumes: The intracellular fluid (ICF) and the interstitial and intravascular plasma fluid, both forming the extracellular fluid (ECF). The urea concentration within both of these aqueous distribution spaces of the body of the ESRD patient is inhomogeneous during dialysis. This is due to strong concentration gradients generated by dialysis. Dialysis has only access to the ECF, because the patient is connected via the cannula positioned within his arterio-venous fistula or graft. Urea once removed by dialysis from extracellular space will be refilled by a concentration gradient across the cell membrane. This is a non-instantaneous process. Typically it takes 30 min to equilibrate 95% of an initial urea gradient over the hypothetical cell membrane if the gradient is not perpetuated by further dialysis. This effect, usually referred as rebound, is the measurable trace of the delayed urea mass transfer across the cell membrane (Schneditz et al. 1993; Spiegel et al. 1995; Leblanc et al. 1996; Garred et al. 1997; Jean et al. 1998, 1999; Alloatti et al. 1998; Yashiro et al. 2004). The rebound phenomenon indicates that urea behaves as if it distributed between two distinct compartments (intracellular and extracellular) (Matthews and Downey 1984), and causes that the simple single pool urea model fails to accurately predict urea concentrations during and after HD.