Chapter 1

Introduction

The chronic renal insufficiency (CRI) represents one of the main problems of public health of this century due to its prevalence and the consequences that it has in the health of those who suffer it, with the social and economic costs that produces. The cost of the renal insufficiency treatment, by means of dialysis or renal transplant, is between 15.000 € and 30.000 € per person per year. At the moment, approximately 500 million people in the world suffer renal disease. Approximately one of each ten citizens lives with renal disease, number that will be increasing in the future. The diabetes and hypertension are the most common causes of kidney failure. These locate the chronic renal insufficiency between the 10 first causes of death in the world.

Renal insufficiency in patients is accompanied by alterations in their water metabolism. The relative distribution in such patients between extracellular (ECW) and intracellular water (ICW) is different compared to that of the healthy population. An increase or reduction in water and sodium is frequently accompanied by metabolic alterations corresponding to oedema (hyperhydration).

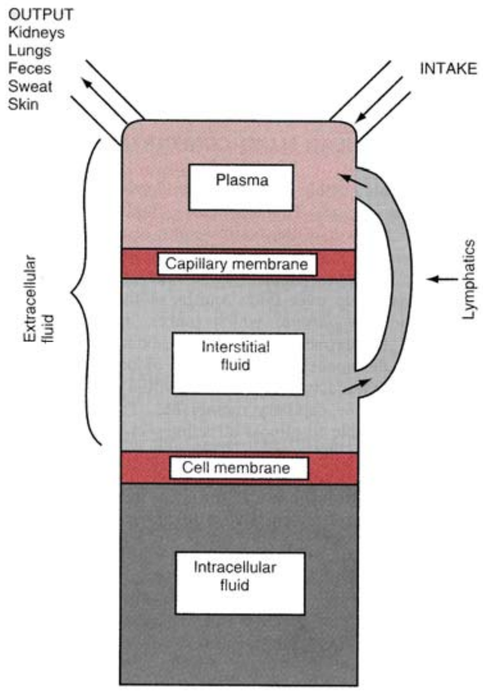

Figure 1.1- Summary of body fluid regulation (Adapted from Guyton and Hall 2001)

The kidneys serve multiple functions, including the following:

1. Excretion of metabolic waste products and foreign chemicals
2. Regulation of water and electrolyte balances
3. Regulation of body fluid osmolality and electrolyte concentrations
4. Regulation of acid-base balance
5. Regulation of arterial pressure
6. Secretion, metabolism, and excretion of hormones
7. Gluconeogenesis

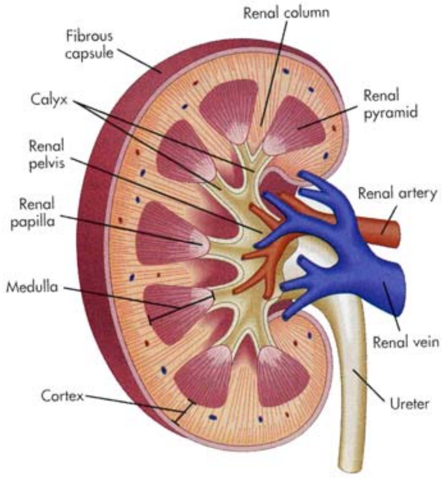

Figure 1.2- Section of Kidney (Adapted from Guyton and Hall 2001)

When the kidneys fail it produces uremic symptoms, desnutrition and muscle wasting, fluid overload, hypertension, hyperkalemia, metabolic acidosis, anemia and bone disease. Dialysis is a therapy which eliminates the toxic wastes from the body when the kidney function fails, and cannot do its job of eliminating these toxic wastes.

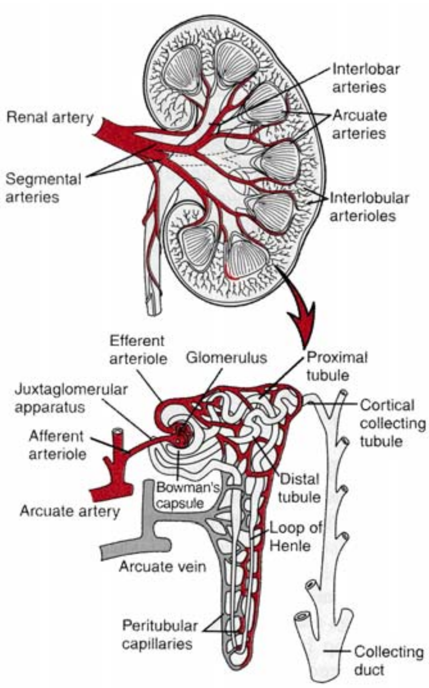

Figure 1.3 Section of the human kidney, and schematic of the microcirculation of each nephon (Adapted from Guyton and Hall 2001)

There are two types of treatment, hemodialysis and peritoneal dialysis. In hemodialysis blood is pumped from the body to a filter made of tiny plastic capillaries. The blood is purified when the waste products diffuse from the blood across the membrane of these tiny capillaries. Purified blood is then returned to the arm. In peritoneal dialysis the bodies own membrane in the peritoneal cavity is used as a filter, and the fluid drained in and out of the abdomen replaces the kidneys in getting rid of the body poisons.

In PD a soft tube called a catheter is used to fill the abdomen with a cleansing liquid called dialysis solution. The walls of the abdominal cavity are lined with a membrane called the peritoneum, which allows waste products and extra fluid to pass from our blood into the dialysis solution (dialysis solution comes in 1.5-, 2-, 2.5-, or 3-liter bags). The solution contains a sugar called dextrose that will pull wastes and extra fluid into the abdominal cavity. These wastes and fluid then leave your body when the dialysis solution is drained. The used solution, containing wastes and extra fluid, is then thrown away. The process of draining and filling is called an exchange and takes about 30 to 40 minutes. The period the dialysis solution is in the abdomen is called the dwell time. A typical schedule calls for four exchanges a day, each with a dwell time of 4 to 6 hours. Different types of PD have different schedules of daily exchanges (Adapted from http://kidney.niddk.nih.gov/kudiseases/pubs/peritoneal)

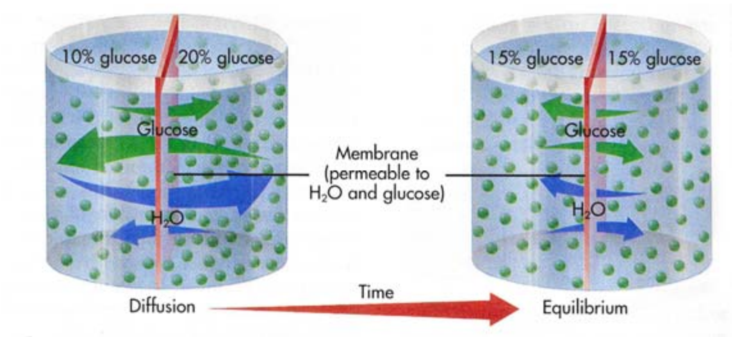

Figure 1.3- Scheme of Peritoneal Diaylsis

The three type of peritneal dialysis are:

1. Continuous Ambulatory Peritoneal Dialysis (CAPD)
2. Continuous Cycler-Assisted Peritoneal Dialysis (CCPD)
3. Nocturnal Intermittent Peritoneal Dialysis (NIPD)

But, the most common form of PD, continuous ambulatory peritoneal dialysis (CAPD), doesn't require a machine. As the word ambulatory suggests, that the patient can walk with the dialysis solution in the abdomen. Other forms of PD require a machine called a cycler to fill and drain the patient`s abdomen, usually while the patients sleep. The different types of cycler-assisted PD are sometimes called automated peritoneal dialysis, or APD.

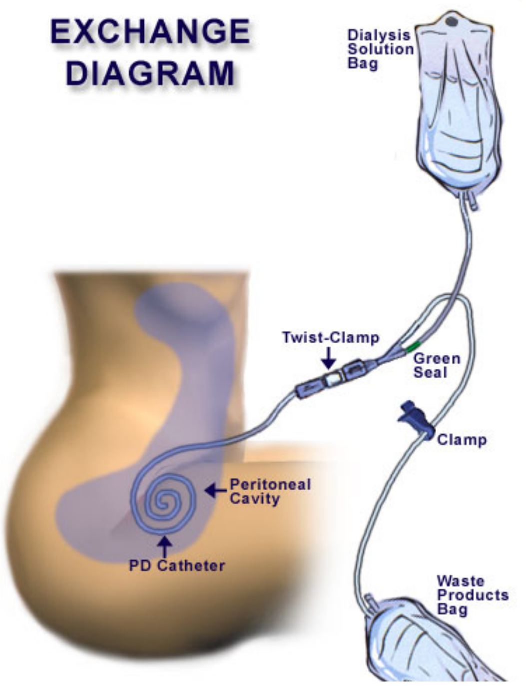

Figure 1.4- Peritoneal dialyis. Exchange diagram (www.renalpatients.co.uk)

The standard catheter for PD is made of soft tubing for comfort. It has Dacron cuffs that merge with your scar tissue to keep it in place. (Dacron is a polyester fabric.) The end of the tubing that is inside your abdomen has many holes to allow the free flow of solution in and out.

Figure 1.5- Peritoneal catheters (www.anandin.com)

Body composition analysis is based on body weight and an examination of soft tissues. Laboratory tests help in the interpretation of variations in body composition associated with metabolic alterations such as hyper- or hyponatremia and hypoalbuminemia detected during the evaluation of fluid compartments.

Several methods (invasives and noninvasives) for the corporal composition analysis in patients with renal insufficiency exist. One of them is the analysis based on body weight and an examination of soft tissues. The laboratory tests help in the interpretation of variations in body composition associated with metabolic alterations. Also, we can use complex techniques to evaluate many body compartments accurately, such as radioactive isotope dilution, hydrodensitometry, dual energy X-ray absorptiometry (DEXA), magnetic resonance imaging, computed axial tomography and neutron activation analysis; or simpler techniques, such as plicometry and ecography. But none of these complex techniques is commonly used due to cost, invasiveness, accessibility and/or need for patient collaboration. The simpler techniques are only accurate in patients whose body composition is stable and normal. Bioelectrical impedance techniques could be an alternative for body composition analysis, as it uses a simple, non-ninvasive, innocuous and repeatable method.

This work analyzes the relation between the electrical impedance measures at 50 kHz and the hydric and nutritional state of the patients undergoing dialysis treatment (hemodialysis and peritoneal dialysis); and the possible future clinical applications.

The thesis includes three fundamental groups: a sample of healthy reference population of 1196 people, with whom the tolerance ellipses were obtained; a sample of 74 patients in hemodiálisis (HD), and one sample of 25 patients in peritoneal dialysis (PD). By personal reasons, the measurements in healthy and hemodialysis samples were made in Cuba and the measurements in peritoneal dialysis were made in Spain. The analysis and processing of the data (healthy, HD and PD) were made in the Tomography and Spectroscopy Electrical Bioimpedance Group of the Division of Instrumentation and Bioengineering (DIB) of the Department of Electronic Engineering of the Universitat Politècnica de Catalunya (UPC), Barcelona.

The measures in healthy and hemodialysis samples were made in the Service of Nephrology of the Saturnino Lora Provincial University Hospital in Santiago de Cuba and in the Chirurgic-Clinic University Hospital in Santiago of Cuba; directed by the Bioimpedance Group of the National Research Centre of Electromagnetism Applied (CNEA) in Santiago de Cuba; and by Prof. Dr Javier Rosell-Ferrer responsible for the Tomography and Spectroscopy Electrical Bioimpedance Group of the Universitat

Politècnica de Catalunya (UPC). The measures in peritoneal dialysis were developed in the Service of Nephrology of the Fundaciò Puigvert of Barcelona under the direction of Prof. Dr Javier Rosell-Ferrer and Dra. Teresa Doñate of the Fundació Puigvert.

In the study two impedance analyzers were used. For HD patients and the reference sample we used the model BioScan: BL – 960141 (Biologica, Barcelona, Spain) (multifrequency). For PD patients we used the model STA-BIA (monofrequency) (RJL-Akern, Florence, Italy). The analyzer BIA-101 (RJL-Systems/Akern, Clinton Twp, MY, USA) was used as a reference to calibrate the BioScan analyzer at 50 kHz.

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The thesis is structured in 10 chapters in the following way:
In Chapter 2 we do a revision of the state-of-the-art analyzing several proposals of different authors about electrode configurations and their applications in patients under hemodialysis or peritoneal dialysis. Also, we explain the bioelectrical impedance vector analysis (BIVA) method and the clinical applications proposed by the Dr Antonio Piccoli in 1994. This method will be used in the thesis in the samples of healthy reference, HD and PD patients. In Chapter 3, we defined the general and specific objectives of the thesis. Chapters 4, 5 and 6 are the nucleous of the thesis, where all the measurement protocols and results are exposed. Each one of these chapters is self-contained and with a structure similar to a magazine article.

Chapter 4 analyzes the impedance vector in a sample of healthy reference population by gender, in the three most important race-ethnicity found in Cuban population.

Chapter 5 analyzes the bioimpedance measures in a HD patient sample divided in stable and critical. In a first study, we have analyzed the multifrequency bioimpedance method before and after the HD sessions with the objective to interpret their hydric state using the Cole model. Then, we made a monofrequency analysis at 50 kHz using the BIVA method, in right-side or whole-body configuration to analyze the movement of the impedance vector (Z/H) before and after the HD session. We also studied the location of the impedance vector (Z/H), that is related with the hydric and nutricional state of the patients, on the tolerance ellipeses of the Cuban reference population obtained in the previous chapter.

In Chapter 6 we analyze the monofrequency, (50 kHz) impedance measures in continuous ambulatory peritoneal dialysis (CAPD) in a sample of patients divided in two groups: stable and unstable. We analyzed three different stimators: Z, Z/H and ZBMI before and after CAPD and we introduced some segmental measures (longitudinal and transversal). Finally, we studied the correlation with clinical parameters and the possible contribution to medical diagnosis.

In Chapter 7 we summarize the conclusions of the thesis derived from the analysis and the results obtained in each study: healthy sample population, sample of HD, and sample of CAPD patients.

In Chapter 8 we propose future research lines according to the experience and the results obtained in healthy populations, HD and CAPD. With special interest in pediatric patients where few published results of electrical impedance techniques are found.

In Chapter 9 all the bibliography reviewed during the investigation is cited.

In Chapter 10 the publications in magazines and communications in conferences derived from the thesis are included. Of them, 18 are national and international conference communications, 3 are articles in magazines indexed in the Journal Citation Report and 3 are articles in local research magazines.