Paediatrica Indonesiana

VOLUME 53 July • 2013 NUMBER 4

Original Article

Renal imaging in children with chronic kidney disease

Wiwit Rahmawati[1], Heru Muryawan[1], Farah Prabowo[2]

Abstract

Background Chronic kidney failure is a cause of death in children. Diagnosing chronic kidney disease is often made by clinical manifestations, laboratory findings and ultrasonography or other imaging tests. Early detection of chronic kidney disease is needed for education and management of the disease.

Objective To describe renal imaging findings and mortality in children with chronic kidney disease.

Methods This was a cross-sectional study on children with kidney diseases who were inpatients at Dr. Kariadi Hospital from January 2008 to June 2011. Data were taken from medical records. Chronic kidney disease was confirmed by clinical manifestations, laboratory findings, and radiologic imaging. Renal ultrasound findings were determined by the radiologist responsible at that time. Results were presented as frequency distributions.

Results Of 37 chronic kidney disease cases, 27 were males and 10 were females. Subjects' most common complaints were dyspnea (7 out of 37) and edema (30 out of 37). Renal ultrasound imaging of subjects with chronic kidney disease yielded the following findings: reduced cortico-medullary differentiation (30 out of 37), bilateral echogenic kidneys (21 out of 37), reduced renal cortex thickness (4 out of 37) and small-sized kidneys (4 out of 37). Eight of the 37 children died. These 8 subjects had the following radiologic imaging findings: both kidneys appeared small in size (4 out of 8), reduced 'renal cortex' thickness (4 out of 8), echogenic kidneys (6 out of 8), and reduced cortico-medullary differentiation (8 out of 8).

Conclusion Renal ultrasound imaging of pediatric subjects with chronic kidney disease revealed findings of reduced cortico-medullary differentiation, bilateral echogenic kidneys, reduced renal cortex thickness, and small kidneys bilaterally. **[Paediatr Indones. 2013;53:193-9.]**

Keywords: *chronic kidney disease, renal imaging, mortality*

Chronic kidney disease (CKD) is a worldwide public health problem and is now recognized as a common condition associated with an increased risk of cardiovascular disease and chronic renal failure (CRF). The Kidney Disease Outcomes Quality Initiative (KDOQI) of The National Kidney Foundation (NKF) defines chronic kidney disease by the following criteria: (1). Kidney damaged for ≥ 3 months, as defined by structural or functional abnormalities of the kidney, with or without decreased glomerular filtration rate (GFR), manifested by 1 or more of the following features: abnormal blood or urine composition, abnormal imaging tests, or abnormal kidney biopsy; (2). Glomerular filtration rate < 60 mL/min/1.73 m^2 for ≥ 3 months, with or without other signs of kidney damage described above.[1-3]

Chronic kidney disease has a prevalence of 1.5-3.0 per 1,000,000 children aged < 16 years. The most common causes of CKD in children are urologic abnormalities (30-33%) and glomerulopathies (25-27%), accounting for more than 50% of the reported causes of end-stage renal disease in children. The

This research was presented at the Asia Oceania Society for Pediatrics Radiology (AOSPR) Congress, Kuta, Bali in November 2011.

From the Department of Child Health[1] and Radiology[2], Diponegoro University Medical School/ Dr. Kariadi Hospital, Semarang, Indonesia

Reprint requests to: Wiwit Rahmawati, Department of Child Health, Diponegoro University Medical School/Dr. Kariadi Hospital. Jalan Dr. Soetomo no 16, Semarang, Indonesia 50231. E-mail: wiwitrahmawati@gmail.com.

other major causes are hereditary nephropathies (16%) as well as renal hypoplasia and dysplasia.[1-3]

Imaging studies of the kidneys are required in patients with CRF. Sonography is the most useful because it can be used to determine the size and configuration of kidneys, independent of renal function. Reduced renal size often indicates an irreversible loss or maldevelopment of renal parenchyma. A dilated collecting system will direct the evaluation toward obstructive uropathy or severe reflux. Renal cystic disease will also be apparent.[4] Imaging tests such as ultrasonography and radionucleide studies help in confirming a CKD diagnosis and may also provide clues to etiology.[2]

The purpose of this study was to describe renal imaging findings and mortality in children with CKD.

Methods

We performed a cross-sectional study on the data of children with CKD who were inpatients at Dr. Kariadi Hospital from January 2008 to August 2011, taken from medical records. Chronic kidney disease diagnoses were made based on clinical manifestations, laboratory findings, and radiologic imaging.

We collected data consisting of gender, age, chief complaints, radiologic imaging, cause of disease, and condition of the patient at the time of hospital discharge (survived or died). Renal ultrasound findings were determined by the radiologist who was responsible at the time of hospitalization. Results are presented in the form of frequency distributions.

Results

There were 37 subjects enrolled in our study. **Table 1** shows the characteristics of subjects, of which the majority were male (27/37). Chief complaints were edema (30/37) and dyspnea (7/37).

All of the 37 cases underwent renal USG examination and mostly had more than one finding. One case who had a reduced corticomedullary differentiation, also had bilateral echogenic kidneys. Another case even had 3 findings (**Figure 1, 2, 3**).

Table 1. Characteristics of subjects

Characteristics, n	n=37
Gender	
Male	27
Female	10
Age group n	
0 - < 1 year	0
1 – 14 years	37
Clinical manifestations (chief complaints)	
Edema	30
Dyspnea	7
Etiology of disease	
Nephrotic syndrome	9
Tumour of vesica urinaria	1
Posterior urethral valve	2
Polycystic kidney disease	1
Spina bifida	1
Unknown	23
Condition of patient at time of discharge from hospital	
Survived	29
Died	8

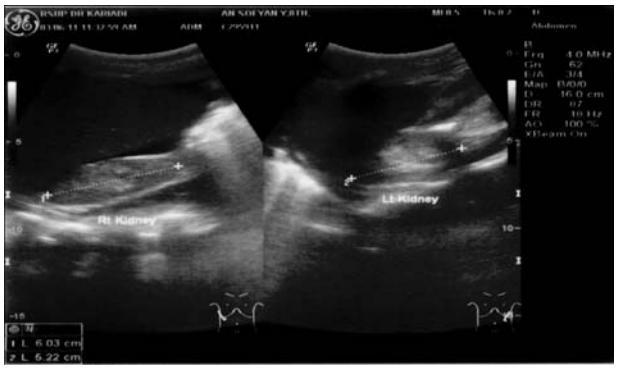

Figure 1. Ultrasound of kidneys showing small size and loss of corticomedullary differentiation.

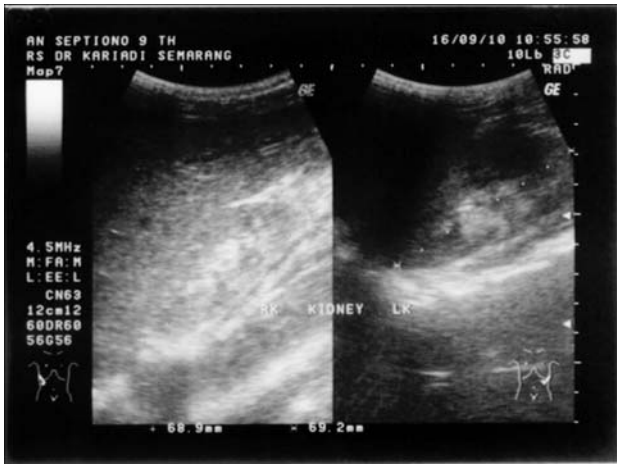

Figure 2. Ultrasound of kidneys showing small size, loss of corticomedullary differentiation and increased echogenicity

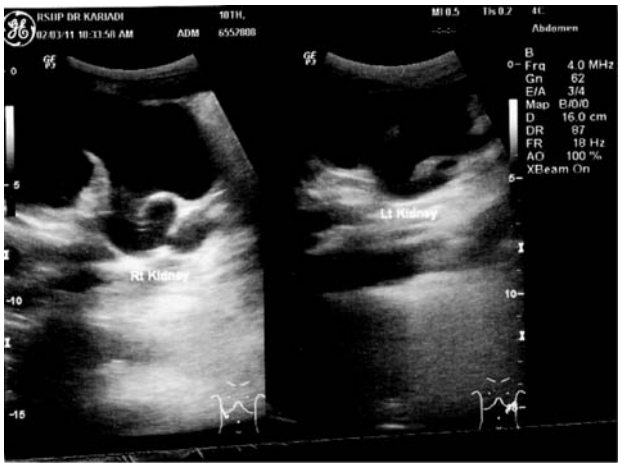

Figure 3. Ultrasound of kidneys showing reduced renal cortex thickness, enlarged size and enlarged pyelocalyx system.

The most common renal ultrasound findings was reduced corticomedullary differentiation **(Figure 4)**. Eight subjects died. Their radiologic imaging findings were as follows: both kidneys appeared reduced corticomedullary differentiation (8/8), reduced renal cortex thickness (4/8), echogenic kidneys (6/8) and small in size (4/8) **(Figure 5).**

Discussion

Incidence rates of pediatric ESRD from the United States Renal Data System Annual Data Report (2007) have remained relatively constant at 14 per million in children under the age of 19 years.[5] Data from the ItalKid Project reported the incidence and prevalence of CKD (defined as GFR < 75 mL/min/ 1.73 m^2) in children aged below 20 years throughout Italy was 12.1 cases per million of the age related population and 74.7 cases per million, respectively.[6] It is not clear whether age is an independent risk factor for CKD progression rates in pediatric population, although it is commonly perceived that renal function deteriorates more rapidly around the time of puberty. Increased body mass at puberty is thought to be associated with systemic and

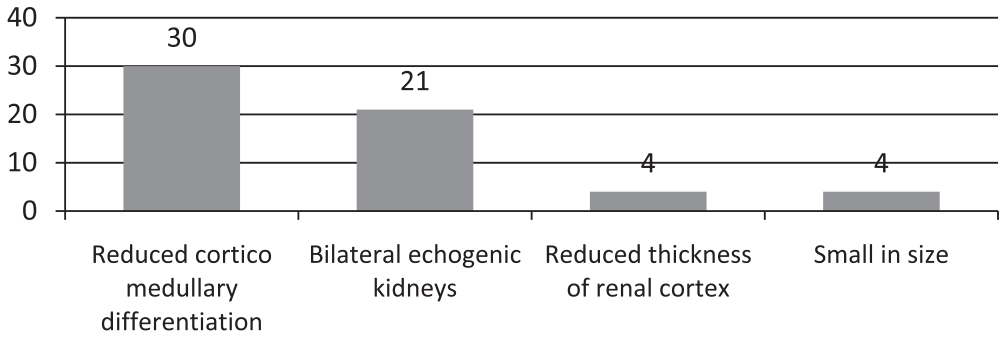

Figure 4. Renal ultrasound findings in all children with CKD

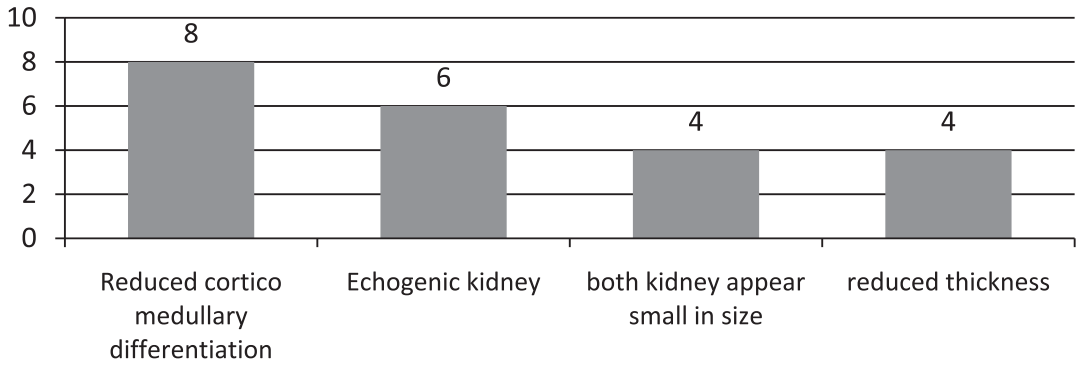

Figure 5. Renal ultrasound findings in subjects who died

Table 2. Causes of chronic renal failure[13-15]

	UK n=683 %	NAPRTCS n=6878 %	Sweden	
			CRF n=118 %	ESRF n=97 %
Congenital abnormalities	**55.1**	**40**	**40.7**	**34.1**
Aplasia/hypoplasia/dysplasia	25.5	15.8	17.8	15.5
Obstructive uropathy	20.2	16.1	19.5	15.5
Reflux nephropathy	7.2	5.4	0	0
Prune belly syndrome	2.2	2.7	3.4	3.1
Hereditary conditions	**17.6**	**13.3**	**26.3**	**35**
Juvenille nephronophthisis/medullary cystic disease	5.3	2.8	6.8	10.3
Polycystlc kidney disease-autosomal recssive	1.8	2.8	5.1	7.2
Hereditary nephritis with or without nerve deafness	1.2	2.4	-	-
Cystinosis	-	-	-	-
Primary oxalosis	2	2.1	5.1	7.2
Congenital nephrotic syndrome	0.2	0.6	9.3	10.3
other hereditary conditions	6.9	2.6	-	-
Glomerulonephritis	**10.3**	**22**	**14.4**	**14.4**
Focal segmental glomerulosclerosis	6.4	11.6	2.5	3.1
Other glomerulonephritis	3.9	10.4	11.9	11.3
Multysystem disease	**5.6**	**6.8**	**3.4**	**4.1**
Lupus erythematosus	-	1.7	-	-
Henoch-Schonlein purpura	1.6	1.4	-	-
Haemolytic uraemic syndrome	3.2	2.7	3.4	4.1
Other multisystem diseases	0.8	1	-	-
Miscellaneous	**9**	**12.6**	**15.2**	**12.4**
Renal vascular disease	4.5	1.7	6.8	4.1
Kidney tumour	1.6	0.6	-	-
Drash syndrome	-	0.6	2.5	3.1
Others	2.9	9.7	5.9	5.2
Chronic renal failure	**2**	**5.4**	-	-
Cause unknown	2	5.4	-	-

intrarenal hemodynamics that accelerate glomerular and interstitial fibrosis. Baseline GFR, albuminuria, hypertension and recurrent febrile urinary tract infections are predictors of more rapid renal function decline.[7] Another study found that the frequency of CKD increases with age and is much more common in adults than children. Among children, CKD is more common in children older than 6 years than in those younger than 6 years of age.[8] In our study, there were 37 cases of CKD, all of them were older children.

Progression to kidney failure depends on the underlying diagnosis, the successful implementation of secondary preventive measures, and the individual patient.[9] Black patient has 2.7 times higher to be ESRD than white patient, maybe cause by genetic susceptibility, socioeconomic problem, and limited access to medical care. Low birth weight, prematurity, and eGFR of 45-49 mL/min/1.73 m^2 also are the risk factors of ESRD.[10,12]

Stage I (normal GFR) and stage II (mild reduced GFR) of CKD usually asymptomatic. Sometimes we can found polydipsia and nocturia. Volume overload, hyperkalemia, metabolic acidosis, hypertension, anemia, bone disease, cardiovascular disease, anorexia, nausea, and vomiting are clinical manifestation of advanced chronic kidney disease.[11] Several signs and symptoms indicate the possibility of CKD and warrant a visit to the nearest hospital emergency department: change in level of consciousness-extreme sleepiness or difficult to awaken, fainting, chest pain, difficulty breathing, severe nausea and vomiting, severe bleeding (from any source), and severe weakness.[2] We found that the most common complaints in our subjects were dyspnea (81%) and edema (19%).

The causes of chronic renal disease, compiled from three sources (UK, NAPRTCS, Sweden), are summarized in **Table 2**. The primary renal diseases of 683 children less than 18 years of age, undergoing renal replacement therapy in 1999, in the UK, are given in

coloum 1 and those of 6878 patients receiving renal transplants before 21 years of age in North America in 1987-2000 are shown in column 2. The causes of CRF (GFR <30mL/min/1.73 m^2) in 118 Swedish children, 97 of whom required renal replacement therapy in 1986-1994 are shown in columns 3 and 4. It is noteworthy that in the Swedish series, no children were identified as having reflux nephropathy as a cause of CRF.[13-15] Congenital abnormalities, which occur more frequently in boys and younger children, account for the largest proportion of cases in all three series. Inherited conditions account for a further 13.3-35%. The cause of ESRF is, therefore, determined prenatally in more than 50% of children requiring renal replacement therapy, which has important implications for antenatal diagnosis and intervention, genetic counselling, and future research.[12] We found the causes of chronic renal disease in our subjects were different from these three sources (UK, NAPRTCS, Sweden). The most common etiology in our subjects was unknown (23/37), followed by nephrotic syndrome (9/37), congenital abnormalities (3/37), hereditary conditions (1/37) and miscellaneous (1/37).

Once CKD occurs, progression to ESRD appears certain. By 20 years of age, 70% of children with CKD develop ESRD.[9] However, the rate of progression depends on the underlying diagnosis, the successful implementation of secondary preventive measures, and the individual patient.[11] Once ESRD developed, those children will have a mortality rate 3 times higher than children without ESRD. The risk of death associated with the year in which renal replacement therapy was initiated, the age of patients at the start of that therapy, and the type of dialysis.[9] In our study, the mortality in patients with CKD was 8/37, but we did not classify the etiolologies of mortality.

Patients with kidney disease commonly undergo ultrasonography examination due to its safety, easy of use, and the information provided. Ultrasonography should be done in patient with obstruction of collecting system, acute or chronic renal failure of unknown etiology. In initially revealing a renal mass, computed tomography (CT) is more sensitive, but to differentiate a simple benign cyst from a more complex cyst or a solid tumor , ultrasonography is preferable.[11]

The diagnosis of chronic renal failure is rarely suspected on clinical grounds alone until GFR has fallen below 20-25 mL/min/1.73m^2. Up to this level the remaining functioning nephrons are capable of regulating body chemistry to adaptive alterations on tubular function, either intrinsic or secondary to events such as development of hyperparathyroidism.[4]

The cortex (the periphery of the kidney tissue) is seen as gray with some darker circles spaced uniformly around the edge. These darker circles correspond to the renal pyramids. A dromedary hump, the incidental finding of an extra mass of normal renal cortex tissue only on the lateral portion of the left kidney, is a normal variant. Relative to the liver parenchyma, the kidney is isoechoic (the same shade of gray) or slightly hypoechoic (a darker shade of gray). The liver is superior to the kidney and superficial (towards the top of the image). It is rather homogeneous (with a fairly regular gray pattern). The kidney is not as homogeneous. These 2 organs can be compared to determine if renal medical disease is present. The center, or hilum, of the kidney contains multiple structures, such as the renal pelvis, blood vessels, nerves, fat, and lymphatics. The fat of the renal sinus is particularly echogenic (bright white). These structures transmit sound differently, and, as the sound waves hit these interfaces between 2 such structures, an echo is generated. Because of this, the renal hilum has increased echogenicity. A prominent column of Bertin is partial hypertrophy of the renal cortex protruding into the renal sinus, and this is another normal variant. The upper pole of the kidney, particularly on the left, can sometimes be hidden behind rib shadows. This fact makes it very important for the sonographer to use breathing techniques and multiple windows to visualize the entire kidney. Most diffuse medical renal conditions have non-specific appearances on ultrasound, with the kidney often appearing normal in early stages of disease. Renal failure may be acute or chronic, and its causes are numerous. If acute, an increase in overall renal size may be observed with many diffuse alterations in the renal echogenicity. However, this may be either hypo- or hyperechoic compared with normal. Either increased or decreased corticomedullary differentiation may also be observed. Although ultrasound is successful in detecting renal parenchymal disease, the acoustic changes are not specific and the cause must usually be diagnosed histologically, ultrasound being invaluable in directing the biopsy procedure.[16]

In chronic renail failure, the kidneys shrink and the cortex thins. The end-stage kidney can be quite tiny and hyperechoic and may be difficult to differentiate from the surrounding tissues. Depending on the cause, either one but generally both of the kidneys are affected.[5] Reliable criteria depicting a shrunken or enlarged kidney have not been published for adults. A renal length of 9-12 cm is considered to be normal, with renal length correlating to body length. The correlation is poor, however. Frequently the right kidney is shorter than the left kidney, whereas renal function estimated by scintigraphy and renal volume estimated by CT are equal for both kidneys. A better correlation was observed between renal volume and body weight or body surface area.[17] Normal renal parenchyma is different, depend on their aged. In children age 6 and older and in adults slightly less echogenic than liver and spleen, but from birth until 6 months of age is slightly brighter than that of the liver. Therefore, the classification of renal parenchyma depends on investigator's experience.[17]

In our study, sonography imaging in children with CKD revealed reduced corticomedullary differentiation (30/37), bilateral echogenic kidneys (21/37), reduced renal cortex thickness (4/37) and the appearance of small-sized kidneys (4/37). Radiologic imaging of the 8 subjects who died revealed the appearance of small-sized kidneys (4/8), reduced thickness of renal cortex (4/8), echogenic kidneys (6/8), and reduced corticomedullary differentiation (8/8). Similarly, Moccia *et al*. reported that reduced corticomedullary differentiation was correlated to chronic kidney failure, but they found no correlations between echogenicity of the kidneys, kidney size, and the degree of decreased renal function.[18]

A limitation of this study was that we did not perform renal histopathology of the patients, staging of the disease, nor did we investigate the etilology of deaths. Also, the study's retrospective design precluded assessing inter- and intra-rater agreement by Kappa testing for the radiologists who assessed the x-ray findings.

In conclusion, renal ultrasound imaging findings in pediatric subjects with kidney failure are reduced corticomedullary differentiation, bilateral echogenic kidneys, reduced renal cortex thickness and small-sized kidneys bilaterally.

References

1. Hogg RJ, Furth S, Lemley KV, Portman R, Schwartz GJ, Coresh J, *et al*. National Kidney Foundation's Kidney Disease Outcomes Quality Initiative clinical practice guidelines for chronic kidney disease in children and adolescents: evaluation, classification, and stratification. Pediatrics. 2003;111;1416-21.
2. Arora P. Chronic renal failure. Medscape reference: Drugs, disease & procedures. 2011 June [cited 2011 July 3]. Available from http://emedicine.medscape.com/article/238798-overview.
3. Whyte DA, Fine RN. Chronic kidney disease in children. Pediatr Rev. 2008;29:335-41.
4. Avner D. Urology imaging. In: Kuhn JP, Slovis TL, Haller JO, editors. Caffey's pediatric diagnostic imaging. 10th ed. Philadelphia: Elsevier; 2004. p. 1818-9.
5. Collins AJ, Foley RN, Herzog C, Chavers BM, Gilbertson D, Ishani A, *et al*. Excerpts from the United States Renal Data System 2007 annual data report. Am J Kidney Dis.2008;51:S1–320.
6. Ardissino G, Dacco V, Testa S, Bonaudo R, Appiani AC, Taioli E, *et al*. Epidemiology of chronic renal failure in children: Data from the ItalKid project. Pediatrics. 2003; 111:e382-7.
7. Gonzales Celedon C, Bitsori M, Tullus K. Progression of chronic renal failure in children with dysplastic kydneys. Pediatr Nephrol. 2007;22:1014-20.
8. Seikaly MG, Ho PL, Emmett L, Fine RN, Tejani A. Chronic renal insufficiency in children: The 2001 Annual Report of the NAPRTCS. Pediatr Nephrol. 2003;18:796-804.
9. Craven A-M, Hawley CM, McDonald SP, Rosman JB, Brown FG, Johnson DW. Predictors of renal recovery in Australian and New Zealand end-stage renal failure patients treated with peritoneal dialysis. Peritoneal Dialysis International. 2007;27(2):184–191.
10. (Best Evidence) Choi AI, Rodriguez RA, Bacchetti P, Bertenthal D, Hernandez GT, O'Hare AM. White/black racial differences in risk of end-stage renal disease and death. Am J Med. 2009;122:672-8.
11. Gulati S. Chronic kidney disease in children. Medscape reference: Drugs, disease & procedures. 2011 June 21 [cited 2011 October 10]. Available from: http://emedicine.medscape.com/article/984358-overview#showall.
12. Rigden SPA. The management of chronic and end stage renal failure in children. In Clinical paediatric nephrology. Webb NJA, Postlethwaite RJ, editors. 3rd ed. New York: Oxford University; 2003. p. 427-9.
13. Lewis M. Report of the Paediatric Renal Registry 1999. In:

Ansell D, Feest T, editors. UK Renal Registry, Bristol, UK. Chapter 15. p. 175-87.

14. Ebsjorner E, Berg U, Hansson S, writing on behalf of the Swedish Pediatric Nephrology Association. Epidemiology of chronic renal failure in children: A report from Sweden 1986-1994. Pediatr Nephrol 1997;11:438-42
15. North American Pediatric Renal Trials and Collaborative Studies. NAPRTCS 2007 Annual Report. Chronic Renal Insufficiency. Section 13. p. 1-18.
16. Peterson AC. Urologic imaging without x-rays - ultrasonography, MRI, and nuclear medicine. Medscape reference: Drugs, disease & procedures. 2008 November 21. [cited 2011 October 10]. Available from: http://emedicine.medscape.com/article/455553-overview.
17. Radermacher J. Ultrasonography of the kidney and renal vessels. I. Normal findings, inherited and parenchymal diseases. Urologe A. 2005;44:1351-63.
18. Moccia WA, Kaude JV, Wright PG, Gaffney EF. Evaluation of chronic renal failure by digital gray-scale ultrasound. Urol Radiol. 1980;2:1-7.