Using Medical-Device Wearable to Improve Hemodialysis Patient’s Live and Access the Holistic Health

W L Chen¹, C-C Wu²,* and C D Kan³,*
¹Department of Engineering and Maintenance, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan.
²Department of Mechanical Engineering, Chienkuo Technology University, Changhua City, Taiwan.
³Division of Cardiovascular Surgery, Department of Surgery National Cheng Kung University Hospital, College of Medicine, National Cheng University Tainan

E-mail: lynnchen.k@gmail.com, wcj@ctu.edu.tw, * kcd56@mail.ncku.edu.tw

Abstract. The increasing incidence of end-stage renal disease (ESRD) is the major burden to health budgets and a threat to public health worldwide. For many years, Taiwan has been ranked the first in the world for the number of hemodialysis patients. For solving the above-mentioned circumstance, we demonstrate the project, here, which goal is to construct the holistic health for hemodialysis patient. The project is to design a wearable medicine-device which can simultaneously measure and monitor the vital sign, including heart rate (HR), pulse oximetry (SPO₂), continuous non-invasive blood pressure (c-NIBP), and total body water (TBW), of hemodialysis patient. By aid of the device we design, hemodialysis patients will get better health care than before. This device comprises three techniques. The first is named “Using phonoangiography technique to early detect the dysfunction of arteriovenous access by arteriovenous access (AVA) stenosis detector”. The stenosis detector based on autoregressive model was employed to simultaneously estimate the status of AVA life cycle and to tract changes in frequency spectra. It helps hemodialysis patients to early detect the dysfunction of AVA and alarms them to make a return visit. The second technique is named “Physiological detecting device for wearable medical device and encoding algorithm development”. The feature of the second technique is to optimize the prognosis by analyzing physiological signals, including water content index, pulse oximetry, and blood pressure in the meanwhile. The third technique is named “Intelligent and smart tourniquet”. This technique aims to preclude AVA dysfunction caused by inappropriate hemostasis.

1. Introduction
The increasing incidence of end-stage renal disease (ESRD) is the major burden to health budgets and a threat to public health worldwide. For many years, Taiwan has been ranked the first in the world for the number of hemodialysis patients. According to the United States Renal Data System 2015 Annual Data Report, 2015, the prevalent and incidence rates of ESRD in Taiwan are 3,138 (per million population, pmp) and 458 respectively. By 2015, total annual cost of the National Health Insurance (NHI) program in Taiwan is up to NT$34,200,000,000 due to the 82,000 ESRD patients. For solving the above-mentioned circumstance, we demonstrate the project, here, which goal is to construct the holistic health for hemodialysis patient. The project is to design a wearable medicine-device which can simultaneously measure and monitor the vital sign, including heart rate (HR), pulse oximetry (SPO₂), continuous non-invasive blood pressure (c-NIBP), and total body water (TBW), of hemodialysis patient. By aid of the device we design, hemodialysis patients will get better health care than before. This device comprises three techniques. The first technique is named “Using phonoangiography
technique to early detect the dysfunction of arteriovenous access by arteriovenous access (AVA) stenosis detector. The stenosis detector based on autoregressive model was employed to simultaneously estimate the status of AVA life cycle and to track changes in frequency spectra. It helps hemodialysis patients to early detect the dysfunction of AVA and alarms them to make a return visit.

Figure 1. Block diagram of the rapid screening system.

Dialysis vascular access stenosis and failure arise from thrombosis to inflow or/and outflow stenosis, due to long-term traumatic puncture for dialysis treatment. The interior of the vascular access exhibits pathological changes, including the formation of intimal hyperplasia and changes in aneurysmal deformability. Any narrowing of the vascular access causes vibration and turbulent flow and also produces bruits murmur sounds [1-3]. AVG has a higher patency rate than an arteriovenous fistula. Ultrasound detection is a useful and noninvasive technique with a highly accurate detection rate for DOS estimation. Through ultrasonic image examinations, > 50% in the vascular accesses results in hemodynamic or clinical abnormality; and > 70% stenosis in a vascular access, percutaneous transluminal angioplasty or surgical treatment is required to dilate the stenotic lesion. However, its techniques and decision-making depend on the operation skill of the physician. In addition, auscultation is a real-time and noninvasive screening method to detect the local conditions of hemodynamic motions during dialysis therapy. However, only one measurement results in lack of information, because frequency sounds are dependent on the stenosis sites, multiple stenosis, monitoring sites, and DOS. Thus, this study proposes the multi-site auscultation method is carried out to increase the accurate estimations in inflow site, mid site, and outflow site, as shown in figure 1.

Previous studies [4-6] show PAG signals can indicate the hemodynamic conditions, such as flow
velocities and flow rates. PAG signals can also be decomposed to time-frequency or frequency-based features and have reported that the changes in frequencies and amplitudes. The characteristic frequencies indicate the spectral peaks between 25Hz and 800Hz. Thus, the characteristic frequencies and frequency spectra can be applied to separate the normal condition from the single and multiple stenosis with different acoustic data length and sampling frequency. Through big data collection, the sound wave patterns can be captured in different data length of the streaming acoustic data along the dialysis vascular access. Based on phonoangiography technique [6], the Burg AR method [7] is used to extract key parameters in the frequency spectra using various combinations of stenotic conditions in an AVG biophysical model, as seen in figure 1. The multiple regression method [8] is employed to find the positive correlation between the key parameters and the DOSs. These big spectral data are further used to establish training data for intelligent machine learning model. In this study, radial-based functions perform the similarity degree measurement for pattern recognition. Then, color relation analysis (CRA) [9] is employed to separate the normal condition from stenotic conditions. The in vitro experimental results will show higher hit rates, true-positive rates, and true-negative rates.

**Figure 2.** An intelligent healthcare chair for physiological measurements in predialysis healthcare.

The second technique is named “Physiological detecting device for wearable medical device and encoding algorithm development”. The feature of the second technique is to optimize the prognosis by analyzing physiological signals, including water content index, pulse oximetry, and blood pressure in the meanwhile. Maintaining adequate dry weight and fluid volume balance is an important issue for dialysis patients. Malnutrition and sodium intake are the primary factors that cause fluid volume imbalance and changes in body weights. Inadequate dry weight control results in higher levels of blood pressures and is related to various complications, such as volume overload, hypertension, congestive symptoms, and cardiovascular diseases. Moreover, inadequate fluid removal provokes hypotension during dialysis treatment. Thus, we propose an early warning tool based on fuzzy color reasoning analysis (CRA) in predialysis healthcare for hypervolemia screening. The anthropometric method is a rapid, non-invasive, and simple technique for estimating the total body water (TBW). In this study, Watson standard formula is employed to estimate cross-sectional standard of TBW with the patient characteristics, including gender, age, height, and weight. Contrast with the experienced anthropometric formulas, Watson formula has < 2% of margin errors and provides a criterion as a reference manner to estimate the TBW in patient’s normal dry weight. In addition, inadequate dry weight and TBW controls will lead to higher blood pressures. The systolic blood pressure (SBP) is also an indicator to evaluate pre-hypertension of 120 – 139 mmHg and hypertension of ≥ 140 mmHg. Therefore, the levels of two indicators, TBW and SBP, are parameterized with fuzzy membership grades to describe the normal and the specific ranges of undervolemia and hypervolemia. A CRA
utilizes a hue-saturation-value color model to design a color perceptual manner for separating normal condition from hypervolemia or undervolemia. Normalized hue angle and saturation value provide a promising visual representation with color codes to realize the patients’ diagnosis. Dialysis patients with hypertension demonstrated that the proposed model can be used in clinical applications. In addition, a healthcare chair is carried out to measure blood pressure and weight in predialysis. The proposed assistant tool integrates an electronic pressure monitor, an electronic weight monitor, and fuzzy CRA is also intended to be established in an intelligent vehicle via a WiFi wireless local area network for cloud computing.

The third technique is named “Intelligent and smart tourniquet”. This technique aims to preclude AVA dysfunction caused by inappropriate hemostasis.

2. Methodology

2.1. PAG Signal Acquisition and Feature Extraction

As shown in figure 3, fast Fourier transform (FFT) algorithm was used with discrete Fourier transform (DFT) to transform the time-domain PAG signal into discrete frequency-domain representation, as follows [10]:

$$x[n] = PAG[n], \quad \Omega = \frac{2\pi f_s}{N}, \quad n = 0, 1, ..., N-1$$

$$y[n'] = \sum_{n=0}^{N-1} x[n] e^{-j\Omega n'}, \quad n' = 0, 1, ..., N-1$$

where $x[n]$ is a discrete time PAG signal (sampling data of original PAG signal, $PAG[n]$); $n$ and $n'$ are the sampling points; and $y[n']$ is a periodic and extended from frequency, $f_s$, to sampling frequency, $f_s$. The DFT was defined in the region between 0 and $f_s$. The first half of the frequency range (from 0 to the Nyquist frequency, $f_s/2$) was sufficient to identify the component frequencies in the FFT data. After the DFT process, a PAG signal can be decomposed into a number of discrete frequencies, $y[n']$, in the specific range from 0 to 1,000 Hz. The frequency spectrum was normalized with the maximum amplitude, $\max[y[n']]$, as

$$\phi[n'] = [\varphi_1, \varphi_2, \ldots, \varphi_{i'}, \ldots, \varphi_p] = \frac{\max[|y[n]|]}{\max[|y[n]|]}, \quad n' = 1, 2, 3, ..., p$$

![Figure 3](image3.jpg)  ![Figure 4](image4.jpg)
Then, the Burg AR method [11-13] was employed to smoothen the frequency spectrum over a continuous range. To obtain the reliable characteristic frequencies, the AR model with AR order was determined to minimize the sum of the residual energies using the Levinson–Durbin recursion algorithm [14-15]. In this study, stenosis combinations are considered at the pre-stenosis site and post-stenosis site, as shown in figure 4, and all the 171 combinations of data sets are used to characterize the primary components of frequency features. PAG signals with different window lengths, $n = 0, 1, 2, \ldots, N - 1$, and the choice of AR order were suggested to achieve a good evaluation analysis by a clinician, including (1) matching the time-limited observation (10-s record for a consumer electronic stethoscope), (2) reducing spectral broadening and spectral leakage, (3) distinguishing the characteristic features in the specific ranges, and (4) enhancing the frequency resolution within the observed window lengths. Two characteristic frequencies could be obtained to determine the spectral peaks between 200–300 Hz and 500–600 Hz in two marginal distributions, symbolized as frequency-1 and frequency-2. Therefore, distinct peaks of power spectral densities (PSDs) can be found as key features for the stenosis screening at the pre-stenosis site and post-stenosis site, symbolized as four combinations (pre-PSD-1, pre-frequency-1), (pre-PSD-2, pre-frequency-2), (post-PSD-1, post-frequency-1), and (post-PSD-2, post-frequency-2). nflow and outflow stenoses.

3. Implementation of Proposed Screening Model

The concept of the fuzzy CRA reason was derived from the fuzzification operations and HSV color model to describe perceptual color relationships for hypervolemia screening. Fuzzification operations can map mathematical input variables into specific gray grades using Gaussian, Z sigmoidal, and S sigmoidal membership functions (MFs). The MF parameters were static or could be changed dynamically based on different HD patients. The proposed screening model could be implemented in an embedded system, as shown in figure 5.

![Figure 5. The proposed fuzzy CRA screening Model and the implementation of screening model in an embedded system.](image)

Its model uses straightforward mathematical computations to achieve the inference procedures for real-time applications. An embedded system (National Instruments™ myRIO-1900, Austin, Texas, U.S.A) can be applied to establish a prototype screening algorithm within a short design cycle. We also integrated electronic body weightometer and blood pressure monitor for weight and blood pressure measurements using a healthcare vehicle/chair. The vehicle was equipped with commercial sensors and was designed to carry out wireless communication for unconstrained physiological monitoring. A WiFi (IEEE 802.11 Standard) wireless local area network was used for linking mobile devices (smart phones, personal digital assistant, or iPad) and portable computers support (laptop), while being operated on 2.4 GHz industrial, science, and medical frequency bands. It was designed for portable devices with low power consumption and short-range communications in common household and mobile appliances.
4. Case Study in Hypertensive HD Patients

The experimental data from hypertensive HD patients were used to verify the proposed screening model. Data of 12 participating subjects, aged 37–67 years, were shown in tables 1 and 2. For these case studies, Watson, Hume, Sahlgrenska formulas were used to calculate the normality TBWs and estimated TBWs. The normal dry weight was prescribed for each patient by the nephrologists. Then the TBWrat was parameterized to rapidly indicate the changes in fluid volume balance, as TBWrat > 1, TBWrat = 1, or TBWrat < 1. In fuzzification operations, the membership grades of TBWrat and SBP were converted to gray grades and three primary color grades using the gray-grade intensity adjustment.

The CRA utilized HSV color model to map gray grades into color codes, green series color, blue series color, and red series color, for the estimation of patients’ diagnosis. For instance, Subject 7# (male, aged 54.9 years) had hypertension and diabetes, a case in which changes in dry weight of +2.0 kg could result in higher SBPs and fluid volume imbalance. Inadequate control of fluid volume or inability to maintain an appropriate dry weight for chronic HD patients was identified as a key factor to cause excess mortality. These problems could lead to chronic volume overload with hypertension and left ventricular hypertrophy, while subsequently causing cardiovascular symptoms and also increasing the patency rate of complications. In addition, some patients removed extra weights to achieve appropriate dry weight, resulting in uncomfortable symptoms. Therefore, it is important to screen early in predialysis stage (3 times a week) and then perform dialysis for volume control or administer antihypertensive drugs.

Subject 7# satisfied with an index, \( H_C = 0.9992 \) (359.7064°) for red series color, and \( S = 0.9794 \); thus, this case study can be agreed as a patient with increasing weight that led to “hypervolemia.” In addition, for Subject 9# (male, aged 66.1 years), the inference results indicated “normal condition,” satisfying with an index, \( H_C = 0.5369 \) (193.2840°) for blue series color.

However, the saturation index, \( S = 0.4485 \), was less than 0.5, due to the subject having slight decreases in weight and prehypertension. This observation led to a suggestion of maintaining the appropriate BMI and dry weight. In contrast with Subject 11# (male, aged 66.9 years), he had changes in weight of −1.7 kg, and the inference results indicated “undervolemia,” satisfying with an index, \( H_C = 0.2950 \) (106.2000°) for green series color, and saturation index, \( S = 0.5303 \). For color code in imaging version, the screening results provided a promising suggestion to gradually control fluid volume and appropriate BMI for HD healthcares. This finding confirmed that the proposed screening model could detect fluid volume imbalance in its early stages in HD patients, six with hypervolemia, two with normal condition, and four with undervolemia. Experimental results for 12 HD subjects are shown in tables 1 and 2.

### Table 1. The experimental results for TBW estimation.

| Patient No. | A (year) | Baseline W (kg) | Change in W (kg) | H (m) | Normality TBW, \( \text{TBW}_{\text{nor}} \) | Estimated TBW, \( \text{TBW}_{\text{est}} \) | Error (%), \( \frac{\text{TBW}_{\text{est}} - \text{TBW}_{\text{nor}}}{\text{TBW}_{\text{nor}}} \) |
|-------------|----------|-----------------|-----------------|------|---------------------------------|---------------------------------|----------------------------------|
| 1           | 37.0     | 92.6            | +1.7            | 1.73 | 48.6                            | 47.1                            | +1.17                            |
| 2           | 43.7     | 94.2            | +1.3            | 1.75 | 48.2                            | 46.9                            | +0.90                            |
| 3           | 46.1     | 61.2            | +1.7            | 1.72 | 37.1                            | 37.6                            | +1.54                            |
| 4           | 52.0     | 75.9            | +1.7            | 1.71 | 41.3                            | 41.7                            | +1.38                            |
| 5           | 53.6     | 87.3            | +1.9            | 1.77 | 45.7                            | 46.3                            | +1.39                            |
| 6           | 54.2     | 62.5            | -2.4            | 1.72 | 36.8                            | 38.0                            | -1.87                            |
| 7           | 54.9     | 81.0            | +2.0            | 1.72 | 42.9                            | 43.4                            | +1.57                            |
| 8           | 56.5     | 78.6            | -1.5            | 1.69 | 41.7                            | 42.3                            | -1.20                            |
| 9           | 66.1     | 67.8            | -0.4            | 1.70 | 37.7                            | 40.1                            | -0.36                            |
| 10          | 66.7     | 64.3            | -0.7            | 1.76 | 36.6                            | 39.3                            | -0.64                            |
| 11          | 66.9     | 58.6            | -1.7            | 1.69 | 33.9                            | 36.2                            | -1.68                            |
| 12          | 67.0     | 59.2            | -1.5            | 1.68 | 33.9                            | 36.1                            | -1.48                            |

**Note:** 1. Symbols, (1) and (4), mean Watson formulas; 2. Symbols, (2) and (5), mean Hume formulas; 3. Symbols, (3) and (6), mean Sahlgrenska formulas.
to Watson, Hume, and Sahlgrenska formulas provided a promising reference with narrow margins of error [2]. For prescribed the normal dry weight, estimated results with a total average error of < 2% for 12 subjects using three formulas are shown in Table 1. The robustness range of normal condition was ±2% of changes in TBW and changes in SBP from 110 to 135 mmHg. That is, the Watson formula has been verified and can be applied to estimate TBW. This indicates that a rapidly, safe, and simple method can be used from a cross-sectional standard for bedside applications in predialysis stage. In this study, the objective was to establish an intelligent vehicle with a warning tool for predialysis healthcare. For physiologic measurements to screen hypervolemia, these findings can provide a promising suggestion to make changes in drink and food and to control extra body weights.

5. Discussion
Cardiovascular disease is the most common cause of mortality in HD patients, and hypertension is also a significant factor for cardiovascular disease pathogenesis. Hypervolemia, hypematremia, and hyperkalemia are important risk factors for their morbidities and mortalities. In previous studies [3, 4, 16-18], the relationship between hypervolemia and malnutrition was regarded to be the key indicator of predisposition to hypertension in HD patients, further preventing the progression of cardiovascular event rate. During dialysis treatment, inadequate fluid removal and blood volume ultrafiltration control or fluid volume imbalance provoked hypotension, associated with clinical symptoms for nursing decreases SBP by > 20 mmHg or decreases mean arterial pressure by 10 mmHg [19]. Hence, anthropometric formulas, such as Watson, Hume, Sahlgrenska, and Lee formulas [20], provide well-known standard methods to estimate TBW. This method might cause large systematic errors, while TBW varied from the average, obese, and overhydrated patients. In particular, in obese patients, the estimated results led to large errors, in average or close-to-average weights, and the Watson, Hume, and Sahlgrenska formulas provided a promising reference with narrow margins of error [2]. For prescribed the normal dry weight, estimated results with a total average error of < 2% for 12 subjects using three formulas are shown in Table 1. The robustness range of normal condition was ±2% of changes in TBW and changes in SBP from 110 to 135 mmHg. That is, the Watson formula has been verified and can be applied to estimate TBW. This indicates that a rapidly, safe, and simple method can be used from a cross-sectional standard for bedside applications in predialysis stage. In this study, the objective was to establish an intelligent vehicle with a warning tool for predialysis healthcare. For physiologic measurements to screen hypervolemia, these findings can provide a promising suggestion to make changes in drink and food and to control extra body weights.

6. Conclusion
A strategy to monitor and control the fluid volume status and hypertension is an important clinical issue in HD patients. Dietary sodium restriction and fluid volume control have been performed to improve malnutrition. A promising method that can provide an accurate assessment to achieve and maintain a stable BMI and dry weight is needed. For prescribed the normal dry weight, Watson

Table 2. The experimental results for hypertensive HD patients.

| Patient No. | A (year) | Baseline W (kg) | Change in W (kg) | H (m) | SBP (mmHg) | TBW_{nor} = TBW / TBW_{nor} | Hypertension | Fuzzy CRA (H_C / S) |
|-------------|----------|-----------------|-----------------|-------|------------|-----------------------------|--------------|------------------|
| 1           | 37.0     | 92.6            | +1.7            | 1.73  | 168.8      | 1.0117 / 1.007 / 1.0131     | √            | 0.9998 / 0.9998 / 0.9998 |
| 2           | 43.7     | 94.2            | +1.3            | 1.75  | 177.2      | 1.0090 / 1.0082 / 1.0100    | √            | 0.9999 / 1.0000 / 1.0000 |
| 3           | 46.1     | 61.2            | +1.7            | 1.72  | 145.6      | 1.0153 / 1.0133 / 1.0173    | √            | 0.9828 / 0.9817 / 0.9834 |
| 4           | 52.0     | 75.9            | +1.7            | 1.71  | 154.6      | 1.0138 / 1.0120 / 1.0151    | √            | 0.8629 / 0.8245 / 0.8766 |
| 5           | 53.6     | 87.3            | +1.9            | 1.77  | 163.6      | 1.0139 / 1.0121 / 1.0149    | √            | 0.9973 / 0.9973 / 0.9973 |
| 6           | 54.2     | 62.5            | -2.4            | 1.72  | 143.3      | 0.9780 / 0.9813 / 0.9758    | √            | 0.9995 / 0.9995 / 0.9995 |
| 7           | 54.9     | 81.0            | +2.0            | 1.72  | 160.6      | 1.0157 / 1.0136 / 1.0169    | √            | 0.9992 / 0.9992 / 0.9992 |
| 8           | 56.5     | 78.6            | -1.5            | 1.69  | 158.8      | 0.9879 / 0.9895 / 0.9868    | √            | 0.9794 / 0.9780 / 0.9803 |
| 9           | 66.1     | 67.8            | -0.4            | 1.70  | 130.0      | 0.9964 / 0.9971 / 0.9962    | X            | 0.9569 / 0.9579 / 0.9515 |
| 10          | 66.7     | 64.3            | -0.7            | 1.76  | 140.0      | 0.9936 / 0.9947 / 0.9933    | X            | 0.5769 / 0.6368 / 0.5639 |
| 11          | 66.9     | 58.6            | -1.7            | 1.69  | 140.0      | 0.9831 / 0.9860 / 0.9817    | √            | 0.9167 / 0.9112 / 0.9167 |
| 12          | 67.0     | 59.2            | -1.5            | 1.68  | 140.4      | 0.9852 / 0.9877 / 0.9838    | √            | 0.9062 / 0.9130 / 0.9004 |

Note: 1. Symbol (1) means Watson formulas; 2. Symbol (2) means Hume formulas; 3. Symbol (3) means Sahlgrenska formulas.
formulas for male and female subjects have been validated to estimate cross-sectional TBW with an average error of <1.2% to indicate the fluid volume imbalance. The proposed fuzzy CRA with the TBW and SBP is used to separate the normal condition from hypervolemia or undervolemia. The fuzzy CRA has a flexibility inference mechanism and no iterative computations to update model parameters. The recognition coefficient, $\mu$, monotonously increases to enhance better contrast in classification applications, while has capability of self-regulation in the primary color grades. Hence, this simple technique can be easily implemented in a tablet PC and an intelligent vehicle via wireless connection, which only requires few patient characteristics, such as $S$, $A$, $W$, and $H$ parameters, as shown by the data in the dashboard in Figure 8. This individualized tool can enhance the priority in data read, cloud computing, and cloud storage for patient demands. In addition, antihypertensive medication is a directed manner to control blood pressure, further preventing the progression of congestive heart failure and improving cardiovascular outcomes. In routine examinations, TBW and blood pressure screenings can be used to evaluate individualized characteristics for drink, food, and pharmacologic controls. We may have a cross-sectional reference to objectively direct dry weight management. In addition, this promising model is an individualized tool for dry weight maintenance in predialysis healthcare.

References
[1] Kurata M 1982 *Numerical Analysis for Semiconductor Devices* (Lexington, MA: Heath)
[2] Selberherr S 1984 *Analysis and Simulation of Semiconductor Devices* (Berlin: Springer)
[3] Sze S M 1969 *Physics of Semiconductor Devices* (New York: Wiley–Interscience)
[4] Dorman L I 1975 *Variations of Galactic Cosmic Rays* (Moscow: Moscow State University Press) p 103
[5] Caplar R and Kuliscic P 1973 *Proc. Int. Conf. on Nuclear Physics* (Munich) 1 517
[6] Cheng G X 2001 *Raman and Brillouin Scattering—Principles and Applications* (Beijing: Scientific)
[7] Szytula A and Leciejewicz J 1989 *Handbook on the Physics and Chemistry of Rare Earths* 12 133
[8] Kuhn T 1998 *Density matrix theory of coherent ultrafast dynamics* *Theory of Transport Properties of Semiconductor Nanostructures* chapter 6 173–214
[9] Kuhn T, Binder E, Rossi F, Lohner A, Rick K, Leisching P, Leitenstorfer A, Elsaesser T and Stolz W 1994 Coherent excitonic and free-carrier dynamics in bulk GaAs and heterostructures *Coherent Optical Interactions in Semiconductors: Proc. NATO Advanced Research Workgroup* (Cambridge, UK, 11–14 August 1993) (NATO Advanced Study Institute, Series B: Physics 330) 33–62
[10] Agarwal R 2010 *Hypertension* 56 512-517
[11] Matthew R W 2010 *Hypertension* 56 341-343
[12] Pogue V, Rahman M, Lipkowitz M, Toto R, Miller E, Faulkner M, Rostand S, Hiremath L, Sika M, Kendrick C, Hu B, Green T, Appel L and Phillips R A 2009 *Hypertension* 53 20-27
[13] Agarwal R, Flynn J, Pogue V, Rahman M, Reisin E and Matthew R 2014 *J. Am. Soc. Nephrol.* 25 1630-1646
[14] Inci A, Kursat S, Kutsal D A, Ulman C, and Veysel Y 2015 *Clinical Nephrology and Urology science* 2 1-8
[15] Lee S W, Song J H, Kim G A, Lee K J and Kim M J 2001 *Nephrol. Dial. Transplant.* 16 91-97
[16] Vallozzi L, Van Torre P, Hertleer C, Rogier H, Moeneclaey M and Verhaevert J 2010 *IEEE Transactions on Antennas and Propagation* 58 (4) 1357-1368
[17] Shoji T, Tsubakihara Y, Fujii M and Imai E 2004 *Kidney International* 66 1212-1220
[18] Ohashi Y, Otani T, Tai R, Okada T, Tanaka K, Tanaka Y, Sakai K and Aikawa A 2012 *Kidney Blood Pressure Research* 36 231-241
[19] Watson P E, Watson I D and R D Batt R D 1980 *Am. J. Clin. Nutr.* 33(1) 27-39
[20] Hwang H S, Hong Y A, Yoon H E, Chang Y K, Kim S Y, Kim Y O, Jin D C, Kim S H, Kim Y L, Kim Y S, Kang S W, Kim N H and Yang C W 2016 Medicine 95(7) 1-8

Acknowledgments
This work is supported in part by the Ministry of Science and Technology, Taiwan, under contract number: MOST 105-2218-E-075B-001 and MOST 105-2221-E-006-087-MY2, duration: March 1, 2016 ~ February 28, 2017 and is also supported in part by the research grant of Kaohsiung Veterans General Hospital, under contract no. VGHKS 105-070.