Applied Medical Informatics
Original Research Vol. 32, No. 1/2013, pp: 43-52

# VIKOR Method for Diabetic Nephropathy Risk Factors Analysis

**Cosmina-Ioana BONDOR*, Ina Maria KACSO, Alina LENGHEL, Dan ISTRATE, and Adriana MUREŞAN**

"Iuliu Haţieganu" University of Medicine and Pharmacy Cluj-Napoca, 8th Victor Babeş, 400012 Cluj-Napoca, Romania.
E-mails: cbondor@umfcluj.ro (*); amuresan@umfcluj.ro

* Author to whom correspondence should be addressed; Tel.: +4-0264-431697; Fax: +4-0264-593847

**Received: 17 December 2012 /Accepted: 10 February 2013 / Published online: 25 February 2013**

**Abstract**
Diabetic kidney disease is an important complication of type 2 diabetes mellitus (T2DM) and has an economic impact in growth due to the increasing prevalence of T2DM. Identification of diabetic kidney disease risk factors is a priority for both the patient and the healthcare system. The aim of our study was to rank the risk factors using VIKOR method applied on a database with patients with T2DM. Data from 53 T2DM patients were analyzed with VIKOR method. 18 possible risk factors were taken in consideration as alternatives and four separate criteria of renal function: two for albumin excretion – quantified as urinary albumin/creatinine ratio (UACR) and two for GFR (glomerular filtration rate). In the top of the VIKOR method hierarchy was serum adiponectin followed by triglycerides, systolic blood pressure, duration of diabetes and age. Malondialdehyde and HDL-cholesterol influenced chronic kidney disease as protective factors (18th, respective 17th position in the hierarchy). VIKOR method brought new information about the similarity between the positions of some factors in the hierarchy.

**Keywords:** Attribute relevance analysis; VIKOR method; Type 2 diabetes mellitus; Chronic kidney disease; Oxidative stress.

## Introduction

The prevalence of diabetes was increasing in recent years due to population growth, aging, increasing prevalence of obesity and sedentary lifestyle reaching 6.4% of adult population [1-2]. In association with increasing diabetes prevalence, will inevitably result increasing proportions of deaths from cardiovascular disease, as well as increased prevalence and associated consequences of other complications of diabetes [3]. One of the common complication of diabetes is chronic kidney disease (CKD) which leading to dialysis or renal transplantation. CKD clinically manifests as a progressively decline of albuminuria and glomerular filtration rate [4]. Slowing disease progression is desirable for diabetes patients because kidney failure worsens quality of life. Analyzing the risk factors for CKD can prevent the onset and progression of this disease. Due to that reason we considered that all information mined from data are important. A hierarchy of risk factors is desirable because we need to know the most important risk factors for CKD. A particular problem discussed in the medical international literature is the role of non-traditional factors of progression of chronic renal failure, like chronic inflammation and oxidative stress [5]. It is believe that oxidative stress, the imbalance of pro- and anti-free radical processes is a risk factor for diabetic

 

nephropathy [6]. Our study measure the relationship of oxidative stress markers and progression of chronic renal failure compared with other factors.

The progression of CKD was analyzed earlier by the decrease of glomerular filtration rate (GFR) or for the increase of urinary albumin/creatinine ratio (UACR) [7-9]. Dwyer stated their concern that they studied only one diagnostic criterion for CKD (UACR) and there are a large proportion of diabetic patients with completely normal UACR (<30mg/g) and with significant kidney dysfunction (GFR≤90 ml/min) [10].

For attribute relevance purpose were used methods like Shannon entropy [11-12], statistics, fuzzy theory [13], artificial intelligence algorithms [14] or neural networks [15].

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is an adequate method for ranking the risk factors when there are multiple criteria for the disease [16]. Several studies applied TOPSIS method in medical field to resolve a multiple criteria decision making problem [17-21].

The VlseKriterijumska Optimizacija I Kompromisno Resenje – in Serbian (VIKOR) method is another multicriterial decision making method (MCDM). Opricovic (1998) and Opricovic and Tzeng (2002) developed this method based on the compromise ranking method of MCDM [22-23]. The compromise solution is a feasible solution, which is the closest to the ideal, and a compromise means an agreement established by mutual concessions [24]. VIKOR method was compared earlier with TOPSIS method [24-26]. The TOPSIS method determines a solution with the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution, but it does not consider the relative importance of these distances when rank the solutions [27-28]. VIKOR method was never applied in medical field (search in PubMed returns 3 results: two in environmental management and one in education) [29-31]. A MCDM problem which can be solved with TOPSIS method is suitable also for VIKOR method [32]. We applied TOPSIS method in medical field to rank risk factors and proved to be an adequate method for this purpose [33-35].

The main objective of our study was to applied VIKOR method for risk factors analysis for CKD in patients with T2DM. We had two situations for patients who had chronic nephropathies: decrease glomerular filtration rate (GFR) or/and increase urinary albumin/creatinine ratio (UACR). Our aim was to analyzed risk factors for decrease GFR and for increase UACR with VIKOR method.

## Material and Method

*Patients and Methods*

We included in the study 53 consecutive type 2 diabetic patients seen in the outpatient settings of the Clinic of Nephrology "Mihai Manasia" Cluj. Inclusion criteria were presence of type 2 diabetes mellitus in the patient history (2 years minimum) and presence of an informed written consent. Exclusion criteria were known nondiabetic renal disease, diabetic kidney disease stage 4–5, a history of uncontrolled hypertension and acute clinical manifest inflammatory/infectious diseases. UACR was determined from a random morning urinary spot. History, clinical examination, blood pressure measurement and anthropometric measurements were obtained. Routine laboratory analysis (automated analyzer), micro albuminuria (immunoturbidimetry), creatininuria (Jaffe), C reactive protein (CRP), total plasma adiponectin (CYBER-ELISA total adiponectin), glycated hemoglobin A1c (chromatographic-colorimetric method -Biogamma) were performed in the Laboratory of Immunology of the Emergency County Hospital Cluj, Romania. Malondialdehyde (MDA) (colorimetric method with thiobarbituric acid), catalase were performed in the Laboratory of the Physiology Department of the University of Medicine and Pharmacy "Iuliu Haţieganu" Cluj, Romania. Glomerular filtration rate (GFR) was estimated according to the abbreviated modification of diet in renal disease (MDRD) formula (GFR=186 × Serum creatinine (μmol/L) -1.154 × age (years) - 0.203 × 0.742 (if female) × 1.210 (if African American)) [36]. This data were used in Bondor et al. to rank the same risk factors with TOPSIS method [35].

*The VIKOR Method*

The VIKOR method was developed to solve a MCDM problem in complex system. It determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights [24]. VIKOR rank the alternatives according to conflicting criteria. It introduces the multicriteria ranking index based on the particular measure of "closeness" to the "ideal" solution [22]

The multicriteria measure for compromise ranking is developed from the $L_p$-metric used as an aggregating function in a compromise programming method [37-38].

Let m decision criteria (symptoms, characteristics) $C_j$, $j=\overline{1,m}$ of the same condition (disease, problem, state) and n alternative solutions $V_i$, $i=\overline{1,n}$. We denote matrix of consequences $A=\left[a_{ij}\right]$, $i=\overline{1,n}, j=\overline{1,m}$.

Development of the VIKOR method started with the following form of $L_p$-metric: $L_{p,i}=\left\{\sum_{j=1}^{m}\left[w_j\frac{a_j^*-a_{ij}}{a_j^*-a_j^-}\right]^p\right\}^{\frac{1}{p}}$, $1\le p\le\infty; i=\overline{1,n}; a_j^*, j=\overline{1,m}$ - positive ideal solution, $a_j^-, j=\overline{1,m}$ - negative ideal solution [24].

The VIKOR method has the following steps [22-23]:

**Step 1.** Determine the best $a_j^*, j=\overline{1,m}$ and the worst $a_j^-, j=\overline{1,m}$ values of all criterion. If the $j^{th}$ function represents a benefit then:

$a_j^*=\max_i a_{ij}, j=\overline{1,m}$ and $a_j^-=\min_i a_{ij}, j=\overline{1,m}$.

**Step 2.** Compute the values $S_i$ and $R_i$, $i=\overline{1,n}$, by the relations:

$$S_i=\sum_{j=1}^{m} w_j\frac{a_j^*-a_{ij}}{a_j^*-a_j^-},$$

$$R_i=\max_i w_j\frac{a_j^*-a_{ij}}{a_j^*-a_j^-},$$

where $w_j$ are the weights of criteria, expressing their relative importance.

**Step 3.** Compute the values $Q_i$, $i=\overline{1,n}$, by the relation:

$$Q_i=t\frac{S_i-S_*}{S^--S^*}+(1-t)\frac{R_i-R^*}{R^--R^*}$$

where

$S^*=\min_i S_i, i=\overline{1,n}$, $S^-=\max_i S_i, i=\overline{1,n}$,

$R^*=\min_i R_i, i=\overline{1,n}$, $R^-=\max_i R_i, i=\overline{1,n}$

and t is introduced as weight of the strategy of "the majority of criteria" (or "the maximum group utility"), here t=0.5.

**Step 4.** Rank the alternatives, sorting by the values S, R and Q, in decreasing order. The results are three ranking lists.

**Step 5.** Propose as a compromise solution the alternative $v'$ which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

**C1**. "Acceptable advantage": $Q(v'')-Q(v')\ge\Delta Q$, where $v''$ is the alternative with second position in the ranking list by Q; $\Delta Q=\frac{1}{n-1}$, n is the number of alternatives.

**C2.** "Acceptable stability in decision making": Alternative $v'$ must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: "voting by majority rule" (when t > 0.5 is needed), or "by consensus" $t \approx 0.5$ , or "with veto" (t < 0.5). Here, t is the weight of the decision making strategy "the majority of criteria" (or "the maximum group utility").

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives $v'$ and $v''$ if only condition C2 is not satisfied, or
- Alternatives $v', v'', \ldots, v^{(M)}$ if condition C1 is not satisfied; and $v^{(M)}$ is determined by the relation $Q(v^{(M)}) - Q(v') < \Delta Q$ for maximum M (the positions of these alternatives are "in closeness"). The best alternative, ranked by Q, is the one with the minimum value of Q. The main ranking result is the compromise ranking list of alternatives, and the compromise solution with the "advantage rate".

The decision criteria $C_j, j = \overline{1,m}$ were given in Table 1.

We take in consideration 18 possible risk factors as alternatives. Because VIKOR method requiring qualitative dichotomial data, we transformed the quantitative variables in qualitative variables using a cut-off (Table 2) [35].

The alternatives $V_i, i = \overline{1,n}$ were gender, age (years)* (≥ 70 years), duration of diabetes (years)* (≥ 10 years), metabolic syndrome (ATP3 2005 criteria) (present/absent), body mass index - BMI (kg/m2) (≥ 25 kg/m2), waist circumference (cm) (≥ 87.5 cm), systolic blood pressure - SBP (mmHg) (≥ 140 mmHg), diastolic blood pressure - DBP (mmHg) (≥ 90 mmHg), total cholesterol (mg/dl) (≥ 200 mg/dl), HDL cholesterol (mg/dl) (≥ 60 mg/dl), triglycerides (mg/dl) (≥ 150 mg/dl), LDL cholesterol (mg/dl) (≥ 110 mg/dl), fasting glucose (mg/dl) (≥ 120 mg/dl), glycated hemoglobin - HbA1c (%) (≥7 %), C reactive protein - CRP (mg/dl) (≥ 1mg/dl), serum adiponectin (μg/ml)* (≥ 5 μg/dl), malondialdehyde - MDA (nmol/ml)* (≥ 4.5 nmol/ml), catalase (U/mg protein)* (≥ 3.5 U/mg protein); (* cut-off with ROC (receiver operating characteristic) curve analysis). The frequencies of their occurrence were given in Table 2 [35].

**Table 1.** The decision criteria $C_j, j = \overline{1,m}$ [35]

| $C_i$ | Criteria | Description | Type of criteria | Weight |
|---|---|---|---|---|
| 1 | UACR≥30 mg/g | 22 (41.51% ) patients with UACR≥30 mg/g | benefit | 1 |
| 2 | UACR<30 mg/g | 31 (58.49% ) patients with UACR<30 mg/g | loss | 1 |
| 3 | GFR/MDRD ≤90 ml/min | 26 (49.05% ) patients with GFR≤90 ml/min | benefit | 1 |
| 4 | GFR/MDRD >90 ml/min | 27 (50.95% ) patients with GFR>90 ml/min | loss | 1 |

UACR = urinary albumin/creatinine ratio; GFR = glomerural filtration rate;
MDRD = multicriteria decision making method

The matrix of consequences $A = \left[a_{ij}\right], i = \overline{1,n}, j = \overline{1,m}$ is presented in Table 2, where $a_{ij}$ were the frequencies of occurrence (%).

## Results

*Application of the VIKOR Method*

**Step 1.** The best $a_j^*, j = \overline{1,4}$ and the worst $a_j^-, j = \overline{1,4}$ values of all criteria were presented in Table 3.

**Step 2.** The values $S_i$ and $R_i$, $i = \overline{1,18}$ were given in Table 4.

**Table 2.** The matrix of consequences $A = [a_{ij}], i = \overline{1,n}, j = \overline{1,m}$ [35]

| Parameters | UACR≥30 mg/g | UACR<30 mg/g | GFR ≤90 ml/min | GFR >90 ml/min |
|---|---|---|---|---|
| Gender (% male) | 40.9 | 33.3 | 61.5 | 65.4 |
| Age (%≥70 years) | 59.1 | 63.3 | 65.4 | 57.7 |
| Duration of diabetes (%≥10 years) | 40.9 | 43.3 | 46.2 | 38.5 |
| Metabolic syndrome (%present) | 72.7 | 73.3 | 80.8 | 65.4 |
| BMI (%≥25kg/m$^2$) | 86.4 | 90 | 88.5 | 88.5 |
| Waist circumference (%≥87.5cm) | 100 | 93.3 | 100 | 92.3 |
| SBP (%≥140mmHg) | 54.5 | 33.3 | 42.3 | 42.3 |
| DBP (%≥90mmHg) | 54.5 | 70 | 61.5 | 65.4 |
| Total cholesterol (%≥200 mg/dl) | 36.4 | 33.3 | 23.1 | 46.2 |
| HDL cholesterol (%≤60 mg/dl) | 90.9 | 90 | 88.5 | 92.3 |
| Triglycerides (%≥150 mg/dl) | 54.5 | 45.5 | 42.3 | 42.3 |
| LDL cholesterol (%≥110 mg/dl) | 36.4 | 40 | 23.1 | 53.8 |
| Fasting glucose (%≥120 mg/dl) | 72.7 | 83.3 | 84.6 | 73.1 |
| HbA1c (%≥7%) | 63.6 | 73.3 | 73.1 | 65.4 |
| CRP (%≥1 mg/dl) | 66.7 | 33.3 | 11.5 | 11.5 |
| Serum adiponectin (%≥5 μg/dl) | 77.3 | 50 | 73.1 | 50 |
| MDA (%≥4.5 nmol/ml) | 9.1 | 46.7 | 26.9 | 34.6 |
| Catalase (%≥3.5 U/mg protein) | 18.2 | 23.3 | 23.1 | 19.2 |

UACR = urinary albumin/creatinine ratio; GFR = glomerural filtration rate;
SBP = systolic blood pressure; DBP = diastolic blood pressure; CRP = C-reactive protein; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; BMI = body mass index; MDA = malondialdehyde; HbA1c = glycated hemoglobin

**Table 3.** The best $a_j^*, j = \overline{1,4}$ and the worst $a_j^-, j = \overline{1,4}$ values of all criteria

| | j=1 (UACR≥30 mg/g) | j=2 (UACR<30 mg/g) | j=3 (GFR ≤90 ml/min) | j=4 (GFR >90 ml/min) |
|---|---|---|---|---|
| $a_j^*$ | 90.9 | 10 | 100 | 5.4 |
| $a_j^-$ | 12.1 | 90.3 | 11.1 | 91.9 |

**Table 4.** The values $S_i$ and $R_i$, $i = \overline{1,18}$

| Parameters | $S_i$ | $R_i$ | Parameters | $S_i$ | $R_i$ |
|---|---|---|---|---|---|
| Gender | 2.13 | 0.69 | HDL cholesterol | 2.20 | 1.00 |
| Age | 1.98 | 0.66 | Triglycerides | 1.88 | 0.54 |
| Duration of diabetes | 1.95 | 0.63 | LDL cholesterol | 2.43 | 0.77 |
| Metabolic syndrome | 1.95 | 0.75 | Fasting glucose | 2.08 | 0.88 |
| BMI | 2.14 | 0.96 | HbA1c | 2.19 | 0.75 |
| Waist circumference | 1.97 | 1.00 | CRP | 1.91 | 1.00 |
| SBP | 1.95 | 0.65 | Serum adiponectin | 1.53 | 0.54 |
| DBP | 2.31 | 0.77 | MDA | 2.53 | 1.00 |
| Total cholesterol | 2.37 | 0.81 | Catalase | 2.19 | 0.96 |

SBP = systolic blood pressure; DBP = diastolic blood pressure; CRP = C-reactive protein; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; BMI = body mass index; MDA = malondialdehyde; HbA1c = glycated hemoglobin

**Step 3.** The minim and maximum values for $S_i$ and $R_i, i = \overline{1,18}$ were: $S^* = 1.53$, $S^- = 2.53$, $R^* = 0.54$, $R^- = 1.00$.

**Step 4.** S, R and Q in decrease order were given in Table 5.

**Table 5.** S, R and Q in decrease order

| Parameters | S |
|---|---|
| Serum adiponectin | 0.00 |
| Triglycerides | 0.18 |
| CRP | 0.19 |
| SBP | 0.21 |
| Duration of diabetes | 0.21 |
| Metabolic syndrome | 0.21 |
| Waist circumference | 0.22 |
| Age | 0.23 |
| Fasting glucose | 0.28 |
| Gender | 0.30 |
| BMI | 0.30 |
| Catalase | 0.33 |
| HbA1c | 0.33 |
| HDL cholesterol | 0.34 |
| DBP | 0.39 |
| Total cholesterol | 0.42 |
| LDL cholesterol | 0.45 |
| MDA | 0.50 |

| Parameters | R |
|---|---|
| Triglycerides | 0.00 |
| Serum adiponectin | 0.00 |
| Duration of diabetes | 0.09 |
| SBP | 0.13 |
| Age | 0.13 |
| Gender | 0.16 |
| HbA1c | 0.23 |
| Metabolic syndrome | 0.23 |
| LDL cholesterol | 0.25 |
| DBP | 0.25 |
| Total cholesterol | 0.29 |
| Fasting glucose | 0.36 |
| Catalase | 0.45 |
| BMI | 0.46 |
| MDA | 0.50 |
| HDL cholesterol | 0.50 |
| CRP | 0.50 |
| Waist circumference | 0.50 |

| Parameters | Q |
|---|---|
| Serum adiponectin | 0.00 |
| Triglycerides | 0.18 |
| Duration of diabetes | 0.31 |
| SBP | 0.33 |
| Age | 0.35 |
| Metabolic syndrome | 0.44 |
| Gender | 0.46 |
| HbA1c | 0.56 |
| Fasting glucose | 0.64 |
| DBP | 0.64 |
| CRP | 0.69 |
| LDL cholesterol | 0.70 |
| Total cholesterol | 0.71 |
| Waist circumference | 0.72 |
| BMI | 0.76 |
| Catalase | 0.78 |
| HDL cholesterol | 0.84 |
| MDA | 1.00 |

SBP = systolic blood pressure; DBP = diastolic blood pressure; CRP = C-reactive protein; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; BMI = body mass index; MDA = malondialdehyde; HbA1c = glycated hemoglobin

**Step 5.** We were interested about the hierarchy of the risk factors, not in only one solution.

The most influenced factor for the state of CKD was serum adiponectin (Q and S had minimum values for serum adiponectin and:

$$Q(\text{trygliceride}) - Q(\text{serum adiponectin}) = 0.18 \geq 0.059,$$

where triglycerides was the alternative with second position in the ranking list by Q and $\Delta Q = \frac{1}{18-1} = 0.059$.

We maintained the condition C1 and C2 to found the second risk factor that influenced CKD. Triglycerides was the second factor in the hierarchy (in Q and S was in the second position and

$$Q(\text{duration of diabetes}) - Q(\text{trygliceride}) = 0.13 \geq 0.059).$$

We continued to rank the factors. The third position was occupied by duration of diabetes, SBP and age:

$$Q(\text{SBP}) - Q(\text{duration of diabetes}) = 0.02 < 0.059,$$

$$Q(\text{AGE}) - Q(\text{duration of diabetes}) = 0.04 < 0.059,$$

$$Q(\text{metabolic syndrome}) - Q(\text{duration of diabetes}) = 0.13 \geq 0.059.$$

In the 6th position was metabolic syndrome and gender:

$$Q(\text{gender}) - Q(\text{metabolic syndrome}) = 0.02 < 0.059,$$

$$Q(\text{HbA1c}) - Q(\text{metabolic syndrome}) = 0.12 \geq 0.059.$$

In the 8th position HbA1c had been ranked:

$$Q(\text{fasting glucose}) - Q(\text{HbA1c}) = 0.08 \geq 0.059.$$

In the 9th position were fasting glucose, DBP, CRP:

$$Q(\text{DBP}) - Q(\text{fasting glucose}) = 0.00 < 0.059,$$

$$Q(\text{CRP}) - Q(\text{fasting glucose}) = 0.05 < 0.059,$$

$$Q(\text{LDL} - \text{cholesterol}) - Q(\text{fasting glucose}) = 0.06 \geq 0.059.$$

In the 12th position were LDL-cholesterol, total-cholesterol and waist circumference:

$$Q(\text{total} - \text{cholesterol}) - Q(\text{LDL} - \text{cholesterol}) = 0.01 < 0.059,$$

$$Q(\text{waist circumference}) - Q(\text{LDL} - \text{cholesterol}) = 0.02 < 0.059,$$
$$Q(\text{BMI}) - Q(\text{LDL} - \text{cholesterol}) = 0.06 \geq 0.059.$$

In the 15th position were BMI and catalase:

$$Q(\text{catalase}) - Q(\text{BMI}) = 0.02 < 0.059,$$
$$Q(\text{HDL} - \text{cholesterol}) - Q(\text{BMI}) = 0.08 \geq 0.059.$$

In the 17th position was HDL-cholesterol:

$$Q(\text{MDA}) - Q(\text{HDL} - \text{cholesterol}) = 0.16 \geq 0.059.$$

On the last position was MDA. The final ranking was given in table 6.

**Table 6.** Final ranking by VIKOR method

| Parameters | Position | Parameters | Position | Parameters | Position |
|---|---|---|---|---|---|
| Serum adiponectin | 1 | Gender | 6 | Total cholesterol | 12 |
| Triglycerides | 2 | HbA1c | 8 | Waist circumference | |
| Duration of diabetes | 3 | Fasting glucose | 9 | BMI | 15 |
| SBP | | DBP | | Catalase | |
| Age | | CRP | | HDL cholesterol | 17 |
| Metabolic syndrome | 6 | LDL cholesterol | 12 | MDA | 18 |

SBP = systolic blood pressure; DBP = diastolic blood pressure; CRP = C-reactive protein; LDL = Low Density Lipoprotein; HDL = High Density Lipoprotein; BMI = body mass index; MDA = malondialdehyde; HbA1c = glycated hemoglobin

## Discussion

The aim of our study (to rank the risk factors of micro albuminuria and GFR in order to evaluate more accurately the risk for CKD (UACR≥30mg/g and/or GFR≤90ml/min) in type 2 diabetes patients with VIKOR method) was fulfilled.

Serum adiponectin was ranked in the first position in the VIKOR hierarchy, which means that had the strongest influence on UACR and GFR compare with the other tested parameters. Serum adiponectin had the highest relative risk (RR) for both criteria UACR and GFR (UACR≥30mg/g, RR=2.06; GFR≤90ml/min, RR=1.65) [35]. TOPSIS method in Bondor and VIKOR method in our study found serum adiponectin to be the best alternative for these criteria. When an alternative was in the top of the ranking for all the criteria, VIKOR method was in concordance and found the serum adiponectin in the first position of the hierarchy.

We can say also that triglycerides, duration of diabetes, systolic blood pressure and age influenced CKD.

MDA influenced CKD as a protective factor. MDA had the lowest mean of the relative risk (RR) for UACR and GFR (UACR≥30mg/g, RR=0.23; GFR≤90ml/min, RR=0.85) except waist circumference for which RR could not be compute [35]. TOPSIS method in Bondor and VIKOR method in our study found MDA to be the worst alternative for these criteria [35]. When an alternative was in the worst position (statistic findings), VIKOR method was in concordance and found the MDA in the last position of the hierarchy.

CRP was in the second position in the UACR hierarchy and in the 10th position in the GFR hierarchy [35]. We consider this situation as a conflicting one. VIKOR method rank CRP in 9th position, TOPSIS method rank CRP in second position [4].

There were other conflicting situations, for systolic blood pressure, triglycerides, metabolic syndrome, fasting glucose, BMI and total-cholesterol were TOPSIS method and VIKOR method found similar results [35].

Spearman correlation coefficient between VIKOR method and TOPSIS method hierarchy position was r=0.70, p=0.001. Spearman correlation coefficient between VIKOR method and RR hierarchy positions for UACR≥30mg/g was r=0.50, p=0.03 compared with TOPSIS method r=0.64, p=0.004. Spearman correlation coefficient between VIKOR method and RR hierarchy positions for GFR≤90ml/min was r=0.51, p=0.03 compared with TOPSIS method r=0.43,

p=0.07. We can say that VIKOR method was significant correlated with both criteria, but TOPSIS method was significant correlated with only one criteria.

VIKOR method gave not only a hierarchy of risk factors as TOPSIS method, but, also provide "clusters" (factors receive the same position in the hierarchy if the difference between them are less then a threshold value) of similarity between risk factors.

VIKOR method was modified for interval numbers [39] and for fuzzy environment [40-41]. VIKOR method is not as popular as TOPSIS method, but this does not mean it's not a good method for solving MCDM problems inclusive in medical field.

## Conclusions

In this case, a disease with multicriteria diagnostic, we found that VIKOR method was an adequate technique for ranking the risk factors. The hierarchy of risk factors was correlated with the hierarchy gave by TOPSIS method. New information was found about the similar position in the hierarchy for some factors.

VIKOR method it's not a multivariate technique, we cannot apply VIKOR to study the effect of association of two or more factors. VIKOR method can be used when we have conflicting criteria or we search for similar alternatives, when we have small samples or if the relative risk cannot be computed (ex. waist circumferences).

## List of abbreviations

| | | |
|---|---|---|
| T2DM | - | type 2 diabetes mellitus |
| VIKOR | - | vlsekriterijumska optimizacija i kompromisno resenje – serbian; multicriteria optimization and compromise solution |
| UACR | - | urinary albumin/creatinine ratio |
| GFR | - | glomerural filtration rate |
| TOPSIS | - | technique for order preference by similarity to ideal solution |
| CKD | - | chronic kidney disease |
| MCDM | - | multicriteria decision making method |
| MDA | - | malondialdehyde |
| BMI | - | body mass index |
| SBP | - | systolic blood pressure |
| DBP | - | diastolic blood pressure |
| HbA1c | - | glycated hemoglobin |
| CRP | - | C-reactive protein |
| ROC | - | receiver operating characteristic |
| RR | - | relative risk |

## Ethical Issues

The study was approved by the ethical committee of our university; informed and written consent was obtained from each participant.

## Conflict of Interest

The authors declare that they have no conflict of interest.

**Acknowledgements**

The author CB was partly supported by European Social Fund within the Sectorial Operational Program - Human Resources Development 2007-2013-POSDRU /89/1.5/S/58965.

**References**

1. Whiting DR, Guariguata L, Weil C, Shaw J. IDF diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Res Clin Pract 2011;94(3):311-321.
2. Morgovan C, Cosma S, Ghibu S, Văleanu MA. The Antidiabetics Market: Tendencies and Research Directions. Appl Med Inf 2010;26(1):42-50.
3. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care 2004;27(5):1047-53.
4. Piwkowska A, Rogacka D, Audzeyenka I, Jankowski M, Angielski S. High Glucose Concentration Affects the Oxidant-Antioxidant Balance in Cultured Mouse Podocytes. J Cell Biochem 2011;112:1661-72.
5. Blezquez-Medela AM, Lopez-Novoa JM, Martınez-Salgado C. Mechanisms involved in the genesis of diabetic nephropathy. Curr Diabetes Rev 2010;6:68-87.
6. Forbes JM, Coughlan MT, Cooper ME. Oxidative stress as a major culprit in kidney disease in diabetes. Diabetes 2008;57:1446-54.
7. Lenghel AR, Kacso IM, Bondor CI, Rusu C, Rahaian R, Gherman Caprioara M. Intercellular adhesion molecule, plasma adiponectin and albuminuria in type 2 diabetic patients. Diabetes Res Clin Pract 2012;95(1):55-61.
8. Parving HH, Lewis JB, Ravid M, Remuzzi G, Hunsicker LG. Prevalence and risk factors for microalbuminuria in a referred cohort of type II diabetic patients: a global perspective. Kidney Int 2006;69:2057-63.
9. Sakaguchi Y, Shoji T, Hayashi T, Suzuki A, Shimizu M, Mitsumoto K, et al. Hypomagnesemia in type 2 diabetic nephropathy: a novel predictor of end-stage renal disease. Diabetes Care 2012;35(7):1591-7.
10. Dwyer JP, Parving HH, Hunsicker LG, Ravid M, Remuzzi G, Lewis JB. Renal Dysfunction in the Presence of Normoalbuminuria in Type 2 Diabetes: Results from the DEMAND Study. Cardiorenal Med 2012;2(1):1-10.
11. Hong SL, Barton SJ, Rebec GV. Altered Neural and Behavioral Dynamics in Huntington's Disease: An Entropy Conservation Approach. PLoS One 2012;7(1):e30879.
12. Lee J, McManus D, Chon K. Atrial Fibrillation detection using time-varying coherence function and Shannon Entropy. Conf Proc IEEE Eng Med Biol Soc 2011;2011:4685-8.
13. Vahidnia MH, Alesheikh AA, Alimohammadi A. Hospital site selection using fuzzy AHP and its derivatives. J Environ Manage 2009;90(10):3048-56.
14. Groşan C, Abraham A, Câmpean R, Tigan Ş. Evolution Strategies for ranking trigeminal neuralgia treatments. Appl Med Inf 2005;17(3,4):72-8.
15. Groşan C, Abraham A, Tigan Ş, Chang T-G, Kim DH. Evolving neural networks for pharmaceutical research. Conf Proc IEEE Hyb Inf Tech 2006:13-9.
16. Bondor CI, Marin M, Renoult E, Kessler M, Ţigan Ş. Hierarchy of risk factors for post kidney transplant diabetes mellitus. Appl Med Inf 2006;18(1-2):25-30.
17. Cimoca G, Dollinger R. Specific quantitative and qualitative attributes for medical ranking/evaluation applications. Appl Med Inf 2001;8(1-2):8-18.
18. Cimoca G. A simple algorithm for comparing hospital units efficiency. Appl Med Inf 2001;8(1-2):3-7.
19. Colosi H, Ţigan Ş. Multiple criteria decision making: an application example in orthodontics. Conf Proc IEEE Autom, Qual and Test, Robotics 2002;II:504-9.

20. Istrate D, Ţigan Ş. Multicriteria hierarchical method for the medical ambulatory services evaluation. Appl Med Inf 2004;14(1-2):71-9.
21. Moldoveanu LM, Ţigan ŞI, Achimaş Cadariu A. Non-Steroidal Anti-Inflammatory Drugs Ranking by Nondeterministic Assessments of Interval Data Type. Appl Med Inf 2012;31(4):1-12.
22. Opricovic S. Multi-criteria optimization of civil engineering systems. Belgrade: Faculty of Civil Engineering; 1998.
23. Opricovic S, Tzeng GH. Multicriteria planning of postearthquake sustainable reconstruction. Comput-Aided Civ Inf 2002;17:211-20.
24. Opricovic S, Tzengb GH. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. EJOR 2004;156:445-55.
25. Opricovica S, Tzengb GH. Extended VIKOR method in comparison with outranking methods. EJOR 2007;178(2)514-29.
26. Mei-Tai Chu MT, Shyu J, Tzeng GH, Khosla R. Comparison among three analytical methods for knowledge communities group-decision analysis. Expert Syst Appl 2007;33:1011-24.
27. Hwang CL, Yoon K. Multiple Attribute Decision Making. New-York: Springer Verlag, Berlin-Heidelberg; 1981.
28. Yoon K. A reconciliation among discrete compromise solutions. JORS 1987;38(3):272-86.
29. Wu HY, Lin YK, Chang CH. Performance evaluation of extension education centers in universities based on the balanced scorecard. Eval Program Plann 2011;34(1):37-50.
30. Chang CL. A modified VIKOR method for multiple criteria analysis. Environ Monit Assess 2010;168(1-4):339-44.
31. Chang CL, Hsu CH. Multi-criteria analysis via the VIKOR method for prioritizing land-use restraint strategies in the Tseng-Wen reservoir watershed. J Environ Manage 2009;90(11):3226-30.
32. Tzenga GH, Lina CW, Opricovic S. Multi-criteria analysis of alternative-fuel buses for public transportation. Energy Policy 2005;33:1373-83.
33. Gherman M, Moldoveanu M, Ţigan Ş. Hierarchy of risk factor in bronchial asthma. Appl Med Inf 2004;14(1-2):35-7.
34. Bondor CI, Marin M, Renoult E, Kessler M, Ţigan Ş. Hierarchy of risk factors for post kidney transplant diabetes mellitus. Appl Med Inf 2006;18(1-2):25-30.
35. Bondor CI, Kacso IM, Lenghel AR, Mureşan A. Hierarchy of risk factors for chronic kidney disease in patients with type 2 diabetes mellitus. Conf Proc IEEE Int Comp Communic and Proc 2012:103-6. doi:10.1109/ICCP.2012.6356170.
36. Levey AS, Greene T, Kusek JW, Beck GJ. A simplified equation to predict glomerular filtration rate from serum creatinine. J Am Soc Nephrol 2000;11:828-30.
37. Yu PL. A class of solutions for group decision problems. Manag Sci 1973;19(8):936-46.
38. Zeleny M. Multiple Criteria Decision Making. New York: Mc-Graw-Hill; 1982.
39. Sayadi MK, Heydari M, Shahanaghi K. Extension of VIKOR method for decision making problem with interval numbers. Appl Math Model 2009;33:2257-62.
40. Sanayei A, Mousavi SF, Yazdankhah A. Group decision making process for supplier selection with VIKOR under fuzzy environment. Expert Syst Appl 2010;37(1):24-30.
41. Vahdani B, Hadipour H, Sadaghiani JS, Amiri M. Extension of VIKOR method based on interval-valued fuzzy sets. Int J Adv Manuf Technol 2010;47:1231-9.