7

Uncovering of body mass index as a risk factor for poor long-term outcome after renal transplantation

Petronella E. Deetman[1],
Jan-Stephan F. Sanders[1], Marc A.J. Seelen[1],
Reinold O.B. Gans[1], Gerjan Navis[1],
and Stephan J.L. Bakker[1,2]

[1]Department of Medicine, Division of Nephrology, University Medical Center Groningen and University of Groningen, the Netherlands;
[2]Top Institute Food & Nutrition, Wageningen, the Netherlands

Transplantation 2015;99(1):e5–6,
accepted in abbreviated form

Abstract

Background. A high BMI is a risk factor for neither graft failure nor mortality in renal transplant recipients (RTR). BMI is not only determined by fat mass, but also by muscle mass. It is unknown whether adjustment for muscle mass could uncover associations of BMI with mortality, by making BMI a better indicator of fat mass. The aim of this study was to investigate whether muscle mass, determined by 24hr urinary creatinine excretion (UCE), confounds associations of BMI with graft failure and mortality in RTR.

Methods. RTR were included who were transplanted between 1993 and 2008. Baseline BMI was determined at one year after transplantation. UCE was measured in repeated 24hr urine collections gathered between 6 and 18 months after transplantation.

Results. In total, 916 RTR were included (mean age 50 [39–59] and 58% was male). Mean BMI was 26 ± 4 kg/m^2 and UCE 12.3 ± 3.0 mmol/24h. During 4.6 (2.5–7.9) years of follow-up for graft failure and 4.9 (2.7–8.4) years for mortality, 77 (8%) RTR developed graft failure and 153 (17%) RTR died. The age- and sex-adjusted association of BMI with graft failure was nonsignificant, (Hazard Ratio [HR], 1.20 [0.96–1.50]; $P = 0.10$), but became uncovered by adjustment for UCE (HR, 1.44 [1.14–1.82]; $P = 0.003$). Similarly, the age- and sex-adjusted association of BMI with mortality was nonsignificant (HR, 1.06 [0.90–1.25]; $P = 0.50$), but became uncovered by adjustment for UCE (HR, .35 [1.13–1.62]; $P = 0.001$).

Conclusions. Adjustment for UCE uncovers an adverse association of high fat mass, for which BMI became a better measure after adjustment for UCE, with both graft failure and mortality. These findings provide an additional potential explanation for the absence of increased risk observed in previous studies.

Introduction

The short-term prognosis of renal transplant recipients (RTR) has improved significantly (1). However, long-term outcome beyond one year after transplantation is disappointing, with success rates of only 50% at approximately 10 years after transplantation (2). One of the reasons for poor outcomes in RTR is the high prevalence of obesity, predisposing patients to dyslipidemia, hypertension, and insulin resistance (3–5).

However, in RTR, obesity (i.e. body mass index [BMI] ≥ 30 kg/m^2) is a risk factor for neither graft failure nor mortality (6,7,8). It has been hypothesized that advances in immunosuppressive therapy, better control of obesity-related comorbidities and increasing experience in kidney transplantation underlie absence of increased risk associated with obesity (6). However, it is important to realize that BMI is not only determined by fat mass, but also by other constituents, particularly muscle mass. Muscle mass could confound the association of BMI with long-term outcomes, because it has associations with long-term outcome opposite of those hypothesized for BMI. This is not only true for renal transplant recipients (9), but also for other populations (10,11).

To our knowledge, it is unknown whether adjustment for muscle mass could uncover associations of BMI with graft failure and mortality, by making BMI a better indicator of fat mass in RTR. To this end, we investigated whether muscle mass, determined by 24 hr urinary creatinine excretion (UCE), confounds associations of BMI with graft failure and mortality in RTR. Because low muscle mass may be the consequence of low protein intake and because low protein intake has been associated with a high risk of graft failure and mortality in RTR (12), we also questioned whether protein intake might also confound associations of BMI with graft failure and mortality. Therefore, our secondary aim was to investigate the effect of urinary urea excretion, as a marker of protein intake, on the association of BMI with graft failure and mortality.

Patients and methods

Study design and population

RTR were eligible for this study if they received a renal transplant for the first time between January 1993 and February 2008 in the University Medical Center Groningen in the Netherlands. Details of the cohort have been published previously (12,13). We made use of the regular patient care program for outpatients. For each visit, RTR are requested to collect a 24 hr urine sample in which several parameters are routinely assessed. Data of total cholesterol, serum creatinine and 24 hr urinary excretion of urea, creatinine

and protein, assessed between 6 and 18 months, were extracted from our hospital laboratory system (12). The median of these measurements was used for analyses. Patient characteristics were retrieved from medical records. BMI was defined as weight (kg) by height (m) squared. Delayed graft function (DGF) was defined as oliguria for more than 6 days after transplantation. The estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation (14).

Shortly after transplantation, RTR are often not yet stable and infections and rejections play a major role. Therefore, data of the first 6 months after transplantation were discarded. Furthermore, we only included patients who survived with a functioning graft beyond 6 months after transplantation and beyond the period of baseline data collection. Finally, patients with missing data on baseline BMI were excluded ($n = 33$, 3.5%), leaving 916 patients eligible for analyses. The Institutional Review Board of the University Medical Center Groningen approved the study protocol, which adhered to the declaration of Helsinki. According to Dutch law, general consent for organ donation and transplantation includes consent for research projects.

Laboratory measurements

Nonfasting blood and urine samples were directly analyzed after collection. Measurements were performed on a Merck Mega Analyzer before March 2006 (Merck, Darmstadt, Germany). From March 2006 onward, measurements were performed on a Roche Modular (Roche Ltd., Mannheim, Germany).

Because there was no substantial difference in UCE and total cholesterol levels, these results were not converted. There was a substantial difference in serum creatinine and urinary protein; therefore, results were converted according to conversion equations provided by our laboratory (Supplementary Table S1). Before March 2006, UCE was measured with the Jaffé method, from March 2006 onwards, UCE was measured with the enzymatic colorimetric assay. UCE was based on a median (interquartile range) of 6 (5–8) collections of 24 hr urine per patient.

Definitions and clinical end points

The primary endpoint of this study was all-cause mortality. The secondary endpoint was graft failure. Graft failure was defined as the need for dialysis or retransplantation. Follow-up was recorded until October 2009. Person-time of follow-up was computed for each participant from 1.5 years after transplantation until the incidence of death or graft failure or after 10 years of follow-up. There was no loss to follow-up.

Statistical analysis

Baseline characteristics of the study population were calculated according to categories of BMI. According to WHO definitions (15), BMI is classified into the following categories; less than 18.5 kg/m^2, 18.5 to 24.9 kg/m^2, 25 to 30 kg/m^2, and 30 kg/m^2 or higher. Because only 14 (1.9%) RTR had a BMI less than 18.5 kg/m^2, we subdivided RTR into the following BMI categories; less than 25 kg/m^2, 25 to 30 kg/m^2, and 30 kg/m^2 or higher. Normally distributed variables are presented as mean ± standard deviation (SD), skewed distributed variables are presented as median (interquartile range), and categorical variables are given as number (percentage). Differences in baseline characteristics across categories of BMI were determined with linear regression. Variables were log-transformed when appropriate.

The effect of potential confounders on the associations of graft failure and mortality was assessed in multivariable Cox regression models. Adjustment for UCE was performed in these models to investigate a potential uncovering effect of UCE on associations of BMI with graft failure and mortality. The final multivariable-adjusted model included age, sex, UCE, diabetes, systolic blood pressure, use of antihypertensive drugs, cholesterol, use of lipid lowering drugs, smoking status, and eGFR. Because several subjects had missing values for one or more variables, multiple imputation was performed for missing data with five imputation cycles. Imputed data was used for Cox regression analyses only. The assumptions of proportionality of hazards and linearity were met.

As a secondary analysis, we tested whether adjustment for urinary urea excretion (UUE), as a marker of protein intake, uncovered associations of BMI with graft failure and mortality. Furthermore, to study whether the uncovering effect of UCE on outcomes was independent of UUE, UUE was added to the multivariable Cox regression models with UCE. As a further secondary analysis, Cox regression analyses were repeated with body weight rather than BMI. In addition, because a BMI lower than 18.5 kg/m^2 may be a sign of underlying chronic disease, which may increase the risk of mortality (16), Cox regression analyses were repeated after exclusion of RTR with a BMI less than 18.5 kg/m^2. To investigate whether transplant era might have influenced our results, Cox regression analyses were repeated after exclusion of RTR who were transplanted before 2000. Statistical analyses were performed using *SPSS* (version 20.0, IBM Inc. Chicago, IL, USA) and *STATA* (version 11.0, StataCorp LP, College Station, Texas, USA). A *P*-value of less than 0.05 was considered statistically significant.

Results

Patient characteristics

A total of 916 RTR were included in the present study. Median age was 50 (interquartile range 39–59) years, 58% was male. Mean BMI was 26 ± 4 kg/m^2, eGFR was 54 ± 18 mL per min per 1.73 m^2 and UCE was 12.3 ± 3.0 mmol/24h. Baseline characteristics are shown in Table 1, for all RTR and according to categories of BMI. BMI was positively associated with age, the use of antihypertensive medication, cholesterol, UCE, UUE, and warm ischemia time. BMI was inversely associated with the eGFR. No associations were found of BMI with sex, diabetes, systolic blood pressure, use of lipid lowering drugs, urinary protein excretion, dialysis vintage, living donor, cold ischemia time, delayed graft function, acute rejection, use of proliferation inhibitors, calcineurin inhibitors, and the use of mTOR inhibitors.

UCE and graft failure

A total of 77 (8%) RTR experienced graft failure during 4.6 (2.5–7.9) years of follow-up. Hazard ratios are shown for the associations of BMI with graft failure in Table 2. In a univariable analysis, BMI was not associated with graft failure. The association of BMI with graft failure remained nonsignificant after adjustment for age and sex, but became uncovered by further adjustment for UCE (Figure 1). This uncovering effect remained after further adjustment for systolic blood pressure, use of antihypertensive drugs, cholesterol, use of lipid lowering drugs, diabetes, smoking status, and eGFR.

UCE and all-cause mortality

A total of 153 (17%) RTR died during 4.9 (2.7–8.4) years of follow-up. Hazard ratio's are shown in table 3. In a univariable Cox regression analysis, BMI tended to be positively associated with mortality. This trend disappeared after adjustment for age and sex, but became uncovered by adjustment for UCE (Figure 1). This uncovering effect remained after further adjustment for potential confounders.

Table 1. Baseline characteristics of the study population and according to categories of BMI.

	Study population	BMI (kg/m^2)			
		< 25	25–30	> 30	***P***
	n = 916	*n = 362*	*n = 382*	*n = 172*	
Men, n	531 (58)	210 (58)	221 (58)	100 (58)	0.96
Age, yr	50 (39–59)	46 (35–57)	51 (41–60)	52 (44–60)	< 0.001
Weight, kg	80 ± 15	70 ± 10	82 ± 9	99 ± 14	<0.001
Diabetes, n (%)	70 (10)	21 (8)	36 (9)	13 (8)	0.28
SBP, mm Hg	144 ± 17	142 ± 17	143 ± 18	144 ± 17	0.058
Use of antihypertensives, n (%)	572 (87)	225 (83)	230 (88)	117 (94)	0.002
Cholesterol, mmol/L	5.7 ± 1.1	5.6 ± 1.1	5.7 ± 1.1	5.9 ± 1.1	< 0.001
Lipid lowering drugs, n (%)	237 (36)	89 (33)	96 (37)	52 (43)	0.14
eGFR, mL/min/1.73 m^2	54 ± 18	56 ± 19	54 ± 17	52 ± 18	0.010
Urinary protein, g/24h	0.3 (0.1–0.3)	0.2 (0.1–0.3)	0.3 (0.1–0.3)	0.4 (0.1–0.4)	0.10
UCE, mmol/24h	12.3 ± 3.0	11.5 ± 2.8	12.5 ± 3.0	13.2 ± 3.1	< 0.001
UUE, mmol/24h	380 ± 98	351 ± 93	385 ± 93	428 ± 98	< 0.001
Dialysis vintage, mo	40 (18–57)	37 (20–57)	37 (17–60)	37 (18–53)	0.26
Living donor, n (%)	239 (26)	103 (29)	93 (24)	43 (25)	0.41
Warm ischemia time, min	40 (32–49)	38 (32–46)	40 (32–49)	41 (35–53)	0.002
Cold ischemia time, hr	17 (3–23)	16 (3–23)	18 (9–23)	17 (3–22)	0.86
Delayed graft function, n (%)	242 (26)	91 (25)	97 (25)	54 (31)	0.050
Acute rejection, n (%)	308 (34)	127 (35)	123 (32)	58 (34)	0.55
Use of PI, n (%)	726 (79)	287 (79)	292 (76)	147 (86)	0.29
Use of CI, n (%)	823 (90)	316 (87)	347 (91)	160 (93)	0.14
Use of mTOR, n (%)	36 (4)	16 (4)	16 (4)	4 (2)	0.15

PI, proliferation inhibitor; CI, calcineurin inhibitor; mTOR, mammalian target of rapamycin

Table 2. Associations of body mass index with graft failure and mortality.

	Graft Failure		Mortality	
	HR (95% CI)	*P*	HR (95% CI)	*P*
No. events	77		153	
Model 1	1.09 (0.87–1.36)	0.45	1.16 (0.99–1.35)	0.067
Model 2	1.20 (0.96–1.50)	0.10	1.06 (0.90–1.25)	0.50
Model 3	1.44 (1.14–1.82)	0.003	1.35 (1.13–1.62)	0.001
Model 4	1.44 (1.09–1.91)	0.012	1.35 (1.10–1.66)	0.004

HRs are shown per each SD increase in BMI (4.3 kg/m²)

Model 1: Crude analysis with body mass index

Model 2: Model 1+age and sex

Model 3: Model 2+UCE

Model 4: Model 3+ systolic blood pressure, use of antihypertensive drugs, cholesterol, use of lipid lowering drugs, diabetes, smoking status, and eGFR

HRs, hazard ratios; BMI, body mass index; UCE, urinary creatinine excretion; UUE, urinary urea excretion

In a secondary analysis, we tested whether UUE, similar to UCE, uncovered the associations of BMI with graft failure and mortality. Indeed, there was an uncovering effect of UUE, albeit less pronounced than UCE (Table 3, model 1 and 2). When the Cox regression analyses with UCE were additionally adjusted for UUE, the uncovering effect of UCE remained essentially similar (Table 3, model 3 and model 4). In a further secondary analysis with body weight rather than BMI, we found that adjustment for UCE also uncovered the associations of body weight with graft failure and mortality (Table 4). In addition, results of Cox regression analyses remained essentially similar after exclusion of 14 RTR with a BMI lower than 18.5 kg/m² as secondary analyses and after exclusion of RTR who were transplanted before 2000.

Table 3. Associations of body mass index with graft failure and mortality (uncovering effect of creatinine excretion).

		Graft Failure		Mortality	
		HR (95% CI)	*P*	HR (95% CI)	*P*
No. events		77		153	
Model 1	BMI	1.44 (1.14–1.82)	0.003	1.35 (1.13–1.62)	0.001
	UCE	0.55 (0.40–0.77)	<0.001	0.49 (0.38–0.63)	<0.001
Model 2	BMI	1.42 (1.11–1.82)	0.005	1.26 (1.05–1.51)	0.015
	UUE	0.62 (0.46–0.84)	0.002	0.63 (0.51–0.78)	<0.001
Model 3	BMI	1.51 (1.18–1.93)	0.001	1.38 (1.15–1.66)	0.001
	UCE	0.65 (0.44–0.97)	0.035	0.55 (0.40–0.74)	<0.001
	UUE	0.77 (0.54–1.09)	0.14	0.85 (0.66–1.10)	0.21
Model 4	BMI	1.44 (1.04–2.00)	0.029	1.37 (1.11–1.68)	0.003
	UCE	0.60 (0.40–0.90)	0.013	0.56 (0.39–0.80)	0.002
	UUE	1.00 (0.62–1.60)	0.98	0.93 (0.67–1.30)	0.67

HRs are shown per each SD increase in BMI (4.3 kg/m²), UCE (3.0 mmol/24h) or UUE (97.8 mmol/24h)

Model 1: BMI, age, sex and UCE

Model 2: BMI, age, sex and UUE

Model 3: BMI, age, sex, UUE and UCE

Model 4: BMI, age, sex, UUE, UCE, systolic blood pressure, use of antihypertensive drugs, cholesterol, use of lipid lowering drugs, diabetes, smoking status, and eGFR

BMI, body mass index; UCE, urinary creatinine excretion; UUE, urinary urea excretion

Secondary analyses

Table 4. Associations of body weight with graft failure and mortality, and the uncovering effect of urinary creatinine excretion.

	Graft Failure		Mortality	
	HR (95% CI)	*P*	HR (95% CI)	*P*
No. events	77		153	
Model 1	1.11 (0.89–1.39)	0.37	1.07 (0.91–1.25)	0.45
Model 2	1.25 (0.97–1.60)	0.084	1.06 (0.87–1.29)	0.57
Model 3	1.58 (1.21–2.07)	0.001	1.46 (1.18–1.81)	0.001
Model 4	1.53 (1.12–2.09)	0.008	1.45 (1.14–1.84)	0.002

HRs are shown per each SD increase in body weight (15 kg)

Model 1: Body weight

Model 2: Model 1+age and sex, and body length

Model 3: Model 2+UCE

Model 4: Model 3+ systolic blood pressure, use of antihypertensive drugs, cholesterol, use of lipid lowering drugs, diabetes, smoking status, and eGFR

HRs, hazard ratios; BMI, body mass index; UCE, urinary creatinine excretion; UUE, urinary urea excretion

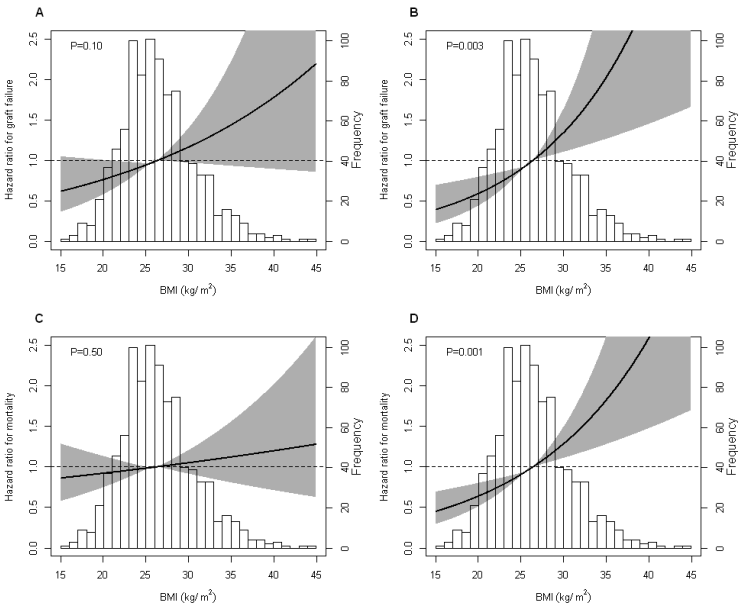

Figure 1. Uncovering of the association of BMI with mortality and graft failure by adjustment for urinary creatinine excretion. A: the age-and sex-adjusted association of BMI with graft failure; B: additional adjustment for urinary creatinine excretion; C: the age-and sex-adjusted association of BMI with mortality; D: additional adjustment for urinary creatinine excretion.

Discussion

In this prospective analysis of a large cohort of RTR, we found a nonsignificant association of BMI with graft failure and mortality in age- and sex-adjusted analyses, which became uncovered after adjustment for muscle mass, which was determined by UCE. Furthermore, we showed a similar uncovering effect of UCE on the association of body weight with graft failure and mortality. The uncovering effect of UCE appeared independent of other potential confounders.

A high BMI (i.e. above 30 kg/m^2) has been associated with dyslipidemia, hypertension, and insulin resistance in the general population (3–5). A high BMI was, therefore, suggested as a risk factor for poor outcomes in various chronic diseases. However, in patients with end-stage renal disease, studies consequently reported paradoxical inverse associations of BMI with mortality (17,18). Similar associations were found in patients with coronary heart disease (19). In renal transplant recipients, both significant and nonsignificant associations of BMI with graft failure and mortality have been reported. A recent systematic review and meta-analysis by Nicoletto et al. concluded that BMI was not significantly associated with graft failure and mortality (6). Nicoletto et al. also observed that the direction of associations of BMI with graft failure and mortality was highly dependent on the transplant era (6). An inverse association was found if studies included RTR were transplanted before 2000. If RTR were transplanted after 2000, nonsignificant associations were found. Our findings are in line with the findings of Nicoletto et al. In the present study that mostly included RTR who were transplanted from 2000 and later, we also found no significant associations of BMI with graft failure and mortality. After exclusion of subjects who were transplanted before 2000, results were essentially similar.

To our knowledge, we are the first who reported an uncovering effect by UCE on associations of BMI with graft failure and mortality. Somewhat analogous to our findings, Kovesdy et al. have found that a nonsignificant association of BMI with mortality became protective after adjustment for waist circumference in RTR (20). It was postulated that this uncovering effect could be explained by the beneficial effects of high muscle mass for which BMI became a better measure after adjustment for waist circumference as a measure of body fat distribution (20). Again analogous to our result, Beddhu et al. investigated patients with end-stage renal disease (ESRD) and reported that the protective effect of a high BMI, as commonly observed in patients with ESRD, was absent in patients with low muscle mass (21).

To date, there was no explanation for the lack of associations of BMI with graft failure and mortality in RTR. It has been suggested that advances in therapeutic regimens in RTR have led to better control of obesity-related comorbidities (6). We speculate that because both high muscle and fat mass contribute to BMI, with opposite associations with outcome (9,20,22), BMI alone is an imperfect estimate of adiposity. It may be possible that BMI becomes a better measure for adiposity after adjusting for UCE as a marker of muscle mass. Another finding of the present study was that UUE uncovered

the associations of BMI with outcomes, which was slightly less pronounced than the uncovering effect of UCE. Hence, we conclude that protein intake may also be an important confounder in the associations of BMI with outcomes, but not as strong as muscle mass.

A limitation of this study is that UCE was measured in 24 hr collections of urine, as 24 hr urine collection is prone to collection errors. However, UCE was measured multiple times over a 6-month period in RTR, which reduces the possibility of collection or measurement errors. Other methods to investigate muscle mass include computerized tomography (CT), magnetic resonance imaging (MRI), and bioelectrical impedance analysis (23). These methods have been proven expensive and in some cases inaccurate, especially in patients with dehydration or edema (23), but also because fat infiltration in muscle may cause overestimation of muscle mass (23,24). A strength of this study is that a large number of stable RTR were included. Another strength of our study is that there was no loss to follow-up.

In conclusion, adjustment for muscle mass, as determined by UCE, seems to uncover an adverse association of high fat mass, for which BMI became a better measure after adjustment for UCE, with both graft failure and mortality. These findings may provide new insight in what we now know as the obesity paradox and may provide an additional potential explanation for the absence of increased risk associated with obesity as previously observed.

References

1. Merville P. Combating chronic renal allograft dysfunction : optimal immunosuppressive regimens. Drugs 2005;65(5):615–631.
2. Lamb KE, Lodhi S, Meier-Kriesche HU. Long-term renal allograft survival in the United States: a critical reappraisal. Am J Transplant 2011 Mar;11(3):450–462.
3. Wilson PW, D'Agostino RB, Sullivan L, Parise H, Kannel WB. Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. Arch Intern Med 2002 Sep 9;162(16):1867–1872.
4. Steiger U, Lippuner K, Jensen EX, Montandon A, Jaeger P, Horber FF. Body composition and fuel metabolism after kidney grafting. Eur J Clin Invest 1995 Nov;25(11):809–816.
5. van den Ham EC, Kooman JP, Christiaans MH, Nieman FH, van Hooff JP. Weight changes after renal transplantation: a comparison between patients on 5-mg maintenance steroid therapy and those on steroid-free immunosuppressive therapy. Transpl Int 2003 May;16(5):300–306.
6. Nicoletto BB, Fonseca NK, Manfro RC, Goncalves LF, Leitao CB, Souza GC. Effects of obesity on kidney transplantation outcomes: a systematic review and meta-analysis. Transplantation 2014 Jul 27;98(2):167–176.
7. Johnson DW, Isbel NM, Brown AM, Kay TD, Franzen K, Hawley CM, et al. The effect of obesity on renal transplant outcomes. Transplantation 2002 Sep 15;74(5):675–681.
8. Massarweh NN, Clayton JL, Mangum CA, Florman SS, Slakey DP. High body mass index and short- and long-term renal allograft survival in adults. Transplantation 2005 Nov 27;80(10):1430–1434.

9. Oterdoom LH, van Ree RM, de Vries AP, Gansevoort RT, Schouten JP, van Son WJ, et al. Urinary creatinine excretion reflecting muscle mass is a predictor of mortality and graft loss in renal transplant recipients. Transplantation 2008 Aug 15;86(3):391–398.
10. Oterdoom LH, Gansevoort RT, Schouten JP, de Jong PE, Gans RO, Bakker SJ. Urinary creatinine excretion, an indirect measure of muscle mass, is an independent predictor of cardiovascular disease and mortality in the general population. Atherosclerosis 2009 Dec;207(2):534–540.
11. Sinkeler SJ, Kwakernaak AJ, Bakker SJ, Shahinfar S, Esmatjes E, de Zeeuw D, et al. Creatinine excretion rate and mortality in type 2 diabetes and nephropathy. Diabetes Care 2013 Jun;36(6):1489–1494.
12. Deetman PE, Said MY, Kromhout D, Dullaart RP, Kootstra-Ros JE, Sanders JS, et al. Urinary Urea Excretion and Long-Term Outcome After Renal Transplantation. Transplantation 2014 Nov 12.
13. Reznichenko A, Snieder H, van den Born J, de Borst MH, Damman J, van Dijk MC, et al. CUBN as a novel locus for end-stage renal disease: insights from renal transplantation. PLoS One 2012;7(5):e36512.
14. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF,3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med 2009 May 5;150(9):604–612.
15. World Health Organization. Global database on Body Mass Index. Available at: http://apps.who.int/bmi/index.jsp?introPage=intro.html.
16. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser 1995;854:1–452.
17. Kalantar-Zadeh K, Abbott KC, Salahudeen AK, Kilpatrick RD, Horwich TB. Survival advantages of obesity in dialysis patients. Am J Clin Nutr 2005 Mar;81(3):543–554.
18. Kalantar-Zadeh K, Block G, Humphreys MH, Kopple JD. Reverse epidemiology of cardiovascular risk factors in maintenance dialysis patients. Kidney Int 2003 Mar;63(3):793–808.
19. Kalantar-Zadeh K, Block G, Horwich T, Fonarow GC. Reverse epidemiology of conventional cardiovascular risk factors in patients with chronic heart failure. J Am Coll Cardiol 2004 Apr 21;43(8):1439–1444.
20. Kovesdy CP, Czira ME, Rudas A, Ujszaszi A, Rosivall L, Novak M, et al. Body mass index, waist circumference and mortality in kidney transplant recipients. Am J Transplant 2010 Dec;10(12):2644–2651.
21. Beddhu S, Pappas LM, Ramkumar N, Samore M. Effects of body size and body composition on survival in hemodialysis patients. J Am Soc Nephrol 2003 Sep;14(9):2366–2372.
22. Alam A, Molnar MZ, Czira ME, Rudas A, Ujszaszi A, Kalantar-Zadeh K, et al. Serum adiponectin levels and mortality after kidney transplantation. Clin J Am Soc Nephrol 2013 Mar;8(3):460–467.
23. Al-Gindan YY, Hankey CR, Leslie W, Govan L, Lean ME. Predicting muscle mass from anthropometry using magnetic resonance imaging as reference: a systematic review. Nutr Rev 2014 Feb;72(2):113–126.
24. Heymsfield SB, Olafson RP, Kutner MH, Nixon DW. A radiographic method of quantifying protein-calorie undernutrition. Am J Clin Nutr 1979 Mar;32(3):693–702.

Supplementary Table S1. Conversion equations for results of laboratory measurements performed on Merck Mega Analyzer or Roche Modular.

Measurement	Conversion equation
Urinary creatinine	No difference
Serum creatinine	$Y^a = (X^b-8)/1.07$
Total cholesterol	No difference
Urinary protein	$Y^a = (X^b+0.05)/1.403$
Urinary urea	$Y^a = (X^b-9)/0.996$

[a]*Roche Modular (Roche Ltd., Mannheim, Germany)*

[b]*Merck Mega Analyzer (Merck, Darmstadt, Germany)*