ORIGINAL ARTICLE

Title:
Replacement of 24-h creatinine clearance by 2-h creatinine clearance in intensive care unit patients

Authors:
Manuel E Herrera-Gutiérrez, MD
Gemma Seller-Pérez, PhD
Esther Banderas-Bravo, MD
Javier Muñoz-Bono, MD
Miguel Lebrón-Gallardo, PhD
Juan F. Fernandez-Ortega, MD

ICU, Hospital Carlos Haya, Av. Carlos Haya s/n, 29010 Malaga, Spain

Corresponding author:
Manuel E. Herrera Gutiérrez
UCI, Hospital Carlos Haya
Av. Carlos Haya s/n
29018 Málaga Spain
mehguci@wanadoo.es

This is an original paper that has not been submitted for publication elsewhere, though partial results of the study were presented at the Annual Congress of the ESICM in Amsterdam (September 2005), and the final results were presented at the Annual Congress of the SEMICYUC (Pamplona, 2006).

Keywords
Acute kidney injury
Creatinine clearance
ICU

Abstract:
Objective: To estimate the usefulness of 2-h creatinine clearance (CrCl) in the ICU and define variables that may reduce agreement.
Design: Prospective study.
Setting: Polyvalent ICU of a university hospital.
Patients: 359 patients.
Interventions: We compared 24-h CrCl as the standard measure, with 2-h CrCl and the Cockroft–Gault equation.
Measurements and results: The 2-h sample was lost in two patients (0.6%) and the 24-h sample was lost in 50 patients (13.9%). The mean Ck-G was 87.4 ± 3.05, with CrCl-2h 109.2 ± 4.46 and CrCl.24h 100.9 ± 4.21 ml/min/1.73 m2 (r2 of 0.88 for CrCl-2h and 0.84 for Ck-G). The differences from ClCr.24h were 21.8 ± 3.3 ($p < 0.001$) for the Ck-G and 8.3 ± 2.6 ($p < 0.05$) for CrCl-2h ($p < 0.05$). In the subgroup of patients with CrCl.24h < 100 ml/min/1.73 m2, the CrCl-24h value was 52.9 ± 2.71 vs. 51.6 ± 2.14 for CrCl-2h (p =ns) and 57.6 ± 2.56 ($p < 0.001$) for the Ck-G. Patients with CrCl < 100 ml/min only showed variability in hyperglycemia during the 24-h period.
Conclusions: In intensive care patients, 24-h CrCl results in a large proportion of non-valid determinations, even under conditions of close monitoring. Two-hour CrCl is an adequate substitute, even in patients who are unstable or who have irregular diuresis where a 24-h collection is impossible. The Cockroft–Gault equation seems less useful in this setting.

Introduction

Acute renal failure (ARF), associated with a high rate of measurement of accompanying disease, is a frequent complication in intensive care units (ICUs) [1, 2]. However, the emphasis is now shifting to a less severe form of renal dysfunction, acute kidney injury (AKI), with the recognition that patients with less severe ARF have important functional impairment and that even moderate impairment is associated with poor outcome.

The glomerular filtration rate (GFR) is the most widely accepted parameter to determine renal function. However, measurement of GFR is not easy in routine clinical practice and an easier way to determine this parameter is desirable [3]. The most frequently used method is measurement of serum creatinine (Crs). However, this method lacks sensitivity and patients whose values are in the upper range of normality can nevertheless have a severely diminished GFR. Isolated results, therefore, are unable to distinguish between AKI patients and those with a chronic process.

Equations based on Crs and anthropometric data can be used to obtain an estimate of the GFR. However, these have failed to prove useful in critically ill patients. Another pos.sibility, 24-h creatinine clearance (CrCl-24h) (using reference values from stable patients) is also less accurate when dysfunction is evolving [4] and, in our experience, it is cumbersome and not suited for repeated measurements [5], explaining its infrequent use in the ICU [2].

Use of shorter collection periods avoids problems related with samples taken over longer periods, and therefore seems more suited for serial determinations, providing an alternative for patient monitoring in the ICU. Our objective was to evaluate 2-h creatinine clearance (CrCl-2h) and the Cockroft–Gault equation (Ck-G) compared with CrCl-24h.

Material and methods

From February to November 2005, we undertook a prospective study in the ICU of Carlos Haya University Hospital (Malaga, Spain), a tertiary center with a 42-bed polyvalent ICU for adult patients. Even though this was an epidemiological, observational study with no intervention, the protocol was approved by the hospital's Ethics and Clinical Research Committee.

The study included patients aged 18 years old or older who were admitted to the ICU with an expected stay of more than 48 h and who had a bladder catheter inserted. Patients in anuria or without a catheter were excluded. The baseline Crs was recorded when available, and in those patients with no baseline Crs we used the Modification of Diet for Renal Disease (MDRD) equation [6].

We measured both CrCl-24h and CrCl-2h (at the start of the 24-h collection period) and

calculated the Ck-G to compare results. The exact time and procedure for all the CrCl-2h collections were supervised personally by the researchers.
The day after admission Crs was measured at the start and the end of the 24 h and CrCl was calculated from the equation [Cr urine (mg/dl)* urine volume (ml) * 1.73/Crs (mg/dl) * minutes * body surface area]. The Ck-G was calculated from the equation [(140-age) * (weight) * (1.73 males, 1.47 females)/72 * Crs]. Clearance was adjusted for body surface area (BSA) and expressed as ml/min/1.73 m2. BSA was calculated from the equation [0.007184 * height (cm)ˆ0.725 * weight (kg) ˆ 0.425].
A data sheet was used to record different variables, including gender, age, weight, height, and previous history of high blood pressure, diabetes mellitus, or chronic renal failure. The Sepsis-related Organ Function Assessment (SOFA) score [7] was recorded, as were all incidents during the 24-h collection period that might have influenced the results: use and type of diuretic, form of administration (bolus dose or continuous perfusion), the administration of nonsteroidal anti-inflammatory drugs and nephrotoxic agents, vasopressors, hypotension (mean pressure < 70 mmHg for more than 2 h), irregular diuresis (< 0.5 ml/kg/h alternating with > 1 ml/kg/h), hyperglycemia (> 180 mg/dl) and oliguria (< 400 ml/24 h).
Statistical analysis
Continuous variables are expressed as the mean ± standard error of the mean (SEM), while qualitative variables are presented as frequencies and percentages. Analysis of the differences between methods and evaluation of the effect of the variables under study was based on the Student t-test, or the Wilcoxon test when n was < 30 or data showed a non-parametric distribution for the mean differences between CrCl-24h and CrCl-2h. Correlation coefficients were calculated and represented by cluster charts.
Bland–Altman plots were used to evaluate dispersion data, plotting on the vertical axis bias (mean difference in variables) and 95% confidence interval (CI) and in the horizontal axis average (test under study + CrCl-24h / 2).
Finally, we plotted a ROC curve and calculated the area under the curve (AUC – 95% CI) for CrCl-2h, Ck-G and 1/Crs (kidney injury was defined as ClCr-24h < 60 ml/min/1.73 m2).

Results
A total of 359 patients were studied, 249 (69.4%) male, with a mean age of 53.5 ± 0.98 years. The SOFA score
on the day of assessment was 4.25 ± 0.15. The Crs was 1.06 ± 0.05 mg/dl at baseline, 1.34 ± 0.06 mg/dl on the day of the study. A previous history of hypertension was present in 126 patients (35.1%), diabetes in 72 (20.1%), liver disease in 34 (9.5%), and chronic renal failure in 28 (7.8%). Events recorded and patient management during the study protocol are presented in Table 1.
The protocol was completed in 307 patients (85.5%). No significant differences in the main variables were found between these patients and those who did not complete the protocol. Of the 52 patients (14.5%) in whom the protocol could not be completed, we failed to obtain the 24-h measurement in 50 (13.9%), whereas we failed to obtain the 2-h measurement in just two (0.6%). In 20 of the 50 patients (40%) in whom CrCl-24h could not be determined the CrCl-2h was < 60 ml/min/1.73 m2.
Seventy-one patients (23%) were admitted to the ICU after trauma, 58 (19%) after planned surgery (including 43 after open-heart surgery), 37 (12%) due to sepsis, 36 (12%) after emergency surgery, 23 (7%) after liver transplantation, and the remaining 82 (27%) for other causes. Table 1 shows the events recorded and the pharmacological therapy during the 24-h follow-up period.
The mean CrCl-24h was 100.9 ± 4.21 ml/min/1.73 m2, the mean CrCl-2h was 109.2 ± 4.46 ml/min/1.73 m2 and the Ck-G was 87.4 ± 3.05 ml/min/1.73 m2. The CrCl-24h and the CrCl-2h agreed in excluding AKI (defined as CrCl.24h < 60 ml/min/1.73 m2) in 186 cases (89.9%) and the two methods agreed in detecting AKI in 87 cases (87%). Using the Ck-G, the two methods agreed in excluding AKI in 174 cases (84.1%) and in detecting it in 84 cases (84%) (Figure 1).

Forty-five patients with Crs < 1.5 mg/dl had a CrCl.24h < 60 ml/min/1.73 m2, and of these 33 (73.3%) had aCrCl-2h < 60 ml/min/1.73 m2 and 30 (66.7%) had aCk-G < 60 ml/min/1.73 m2. The mean difference between the evaluated methods and CrCl-24h was 21.8 ± 3.3 ml/min/1.73 m2 ($p < 0.001$) for Ck-G (95% CI –94.69 to 138.43) and 8.3 ± 2.6 ml/min/1.73 m2 ($p < 0.05$) for CrCl-2h (95% CI –83.02 to 99.7) (Fig. 1).
Since the difference increases as CrCl-24h rises, we analyzed separately those patients with CrCl.24h < 100 ml/min/1.73 m2. In this group the CrCl-24h was 52.9 ± 2.71 ml/min/1.73 m2, versus 51.6 ± 2.14 (p = ns) for CrCl-2h and 57.6 ± 2.56 ($p < 0.001$) for the Ck-G. The bias is shown in Fig. 1.
The correlation coefficient (r2) was 0.88 for CrCl.24h vs. CrCl-2h and 0.84 for CrCl-24h vs. Ck-G. The differences remained after considering the group of patients with CrCl-24h < 100 ml/min/1.73 m2 (CrCl-24h vs. CrCl-2h, r2 = 0.89 and CrCl-24h vs. Ck-G, r2 = 0.84).
The presence of hypotension, oliguria, hyperglycemia or the use of diuretics (mannitol) was associated with increased variability, which was also more evident in the men as compared with the women. However, in the subgroup of patients with CrCl-24h < 100 ml/min/1.73 m2, only the presence of hyperglycemia influenced the difference between CrCl-24h and CrCl-2h (Table 2).
Finally, we calculated the area under the curve for 1/serum creatinine (AUC 0.86; 95% CI 0.82–0.91), Ck-G (AUC 0.91; 95% CI 0.88–0.95) and CrCl-2h (AUC 0.96; 95% CI 0.94–0.98) to detect kidney injury (CrCl.24h < 60 ml/min/1.73 m2) (Figure 2).

Discussion

We showed a close correlation between CrCl-24h and ClCr-2h, this latter measurement surpassing Ck-G and Crs for the diagnosis of kidney dysfunction in ICU patients. This association remained even with the use of diuretics or in the presence of low or irregular diuresis.
Acute renal failure is an important cause of morbidity and mortality in the ICU [1, 2, 8, 9]. This concept, however, is now being replaced by AKI (renal injury as a progressive process), such that early recognition of AKI may delay or prevent ARF [3]. Clinical research is dedicating considerable effort to finding early markers of kidney failure [10–12].
AKI can be defined as a decline in GFR [3], which can be estimated by different means: (1) the urine flow,
(2) the accumulation of molecules or (3) the rate of elimination of these substances [12]. Diuresis is sensitive to changes in renal hemodynamics and can anticipate other biochemical markers, but it is associated with a lack of specificity [12, 13]. CrCl-2h is able to detect a decline in GFR independent of the urine flow and can be of use in patients with a normal diuresis.
As measurement of Crs reflects its rate of elimination, is easily performed in any clinical setting, and measurement of GFR is not often required in clinical practice, Crs has so far been the most widely used technique for evaluation of kidney function [14]. However, it is affected by different variables, and kinetic studies show that Crs increments during AKI do not always reflect changes in GFR [15, 16]. Nevertheless, it is possible to measure CrCl over a shorter period universally and easily, providing a better measurement of kidney dysfunction than isolated Crs (as shown in our ROC curves). According to our data, about 25% of patients with Crs < 1.5 mg/dl had an important decrease in GFR (CrCl < 60 ml/min) and in a study by Hoste et al. this figure was even higher, with 46% of the patients having a CrCl < 80 ml/min [17]. Despite these data and the fact that an isolated Crs determination does not consider progressive changes during the process of AKI [13, 18], this measurement is still widely used, and few studies currently stratify patients according to changing parameters [19].
Different equations can be used to estimate GFR based on anthropometric data without urine sampling, such as those developed by Jelliffe et al. [20], the Cockroft–Gault equation [21] or the MDRD equation [6]. These equations provide a good approximation to CrCl-24h for the general population, but not in the ICU environment. After studying 24 critical care patients, Hoste et al. [17] concluded that the Ck-G and MDRD equations did not perform well in their ICU population. Our results show that the Ck-G equation is effective in estimating the CrCl-24h, but

not as close as the CrCl-2h: an average difference of 18–20 ml/min may be acceptable, although a more precise estimate is advisable. Interestingly, these authors selected a short collecting time to calculate creatinine clearance as an adequate measure for their ICU patients, instead of the usual 24-h interval.

The gold standard for estimating GFR involves injecting a substance (e. g., inulin or a radioactive marker) and measuring its elimination. However, bearing in mind the difficulties this causes in clinical practice, the clearance of an endogenous substance already presents in the body and filtered by the glomeruli (creatinine) is considered to be equally effective, although not as sensitive [22]. CrCl-24h is nowadays the most widely used method for estimating the GFR, though in our experience it is of limited use in the ICU [2]. Due to the inevitable delay in measuring CrCl-24h and its requirements for a steady renal function, it is not well suited for monitoring AKI in unstable patients [4], who would benefit from measurement of CrCl at shorter intervals. O'Connell et al. [23] evaluated short-time measures in non-critical elderly patients, detecting a good correlation with 24-h sampling.

However, little information exists about critical patients. Baumann et al. [24] compared 2-h and 24-h CrCl in 10 trauma and post-surgery patients, finding less than 20% variability with no cyclic variations during the day. Wilson and Soullier [25] measured 2-, 4-, 6-, 8-, 12-and 24-h CrCl in 30 critical patients, recording a greater difference than in our series (18 ml/min) and detecting the largest differences in patients with irregular diuresis (our results demonstrate that an irregular flow of urine does not invalidate 2-h sampling). Herget-Rosenthal et al. [26] found CrCl-2h to be similar to CrCl-24h in 30 critical patients and highlighted the possibility of obtaining the results on the same day (this being an important consideration in critical patients), though they did not study which factors could hamper the relationship between these two measures. Our investigation confirms their results in a larger ICU population and furthermore adds to their data new information on common variables and procedures applied in the ICU. We detected some variables that could affect the CrCl-2h measurement in the whole population, principally those concerning hyperosmolar conditions – hyperglycemia and mannitol administration – though interestingly this negative effect was lost when studying those patients with CrCl < 100 ml/min. In this group, only hyperglycemia interfered with the results. Use of furosemide did not change the association between the two measures, an important point if we consider that 70% of AKI ICU patients receive diuretics during admission, according to the BEST study [27] and in agreement with the high rate of use in our series.

Several studies have been published on different early markers for AKI [28]. Of these, cystatin C (Cys-
C) appears to be an extremely reliable marker in critical patients [29, 30], and Herget-Rosenthal et al. [31] noted in a study stratifying patients according to the RIFLE scale that Cys-C detected AKI before the diagnosis was established by Crs. On the other hand, this technique must be confirmed in an ICU setting, and the studies reported so far have compared Cys-C with CrCl-24h [30], showing very similar results to those found in our study with CrCl-2h. Thus, our results suggest that until Cys-C is validated and becomes a standard measure, CrCl-2h is an adequate substitute for CrCl-24h.

We chose a short time for urine collection be-cause in a previous epidemiological study we found that CrCl-24h was scarcely used in the ICU [2]. In fact, the principle agreed on, after using equations to estimate CrCl without urine collection, is that "collecting urine specimens is difficult and unreliable in all but research situations" [20], and this point was proven in our study when we found a loss rate of nearly 15%. The fact that we did not lose an appreciable number of samples of CrCl-2h is a strong argument for its use, instead of CrCl-24h, for monitoring kidney function in the ICU. Although the high rate of losses might be an important factor in our study, both groups (losses and cases) were checked for differences and found to be well balanced, so this does not invalidate our conclusions.

We detected a rather large variation in the whole series, as shown in Fig. 1, though this was mainly due to patients with a high CrCl-24h (Fig. 3). Analysis of just those patients with a CrCl < 100 ml/min gave similar data to those considered adequate in other studies [32].

Limitations of the study

The main concern with our research comes from the fact that this is a single-center,

epidemiological study that reflects the specific case-mix in our unit. We acknowledge that the results can be strongly affected by our population characteristics and certain specific therapeutic approaches used (a high proportion of heart surgery or liver transplant patients without AKI treated with diuretics to achieve adequate fluid management). We therefore show relevant data to enable comparisons with different ICU populations.
In summary, measurement of 24-h creatinine clearance is, in our experience, difficult to perform and results in a delay in the evaluation of kidney function for a high proportion of patients due to technical reasons. In ICU patients for whom 24-h urine collection is not available, 2-h CrCl can be a substitute, because it is better than just one single measurement, it provides comparable results to CrCl.24h, is easier to perform and can be achieved in a safe, rapid and easily reproducible way. Nevertheless, 24-h CrCl should not yet be eliminated as further studies are required to challenge and confirm this concept.

References

1. Liaño F, Junco E, Pascual J, Madero R, Verde E, Madrid Acute Renal Failure Study Group (1988) The spectrum of acute renal failure in intensive care unit compared with that seen in other settings. Kidney International 53:S16–S24

2. Herrera-Gutiérrez ME, Seller-Pérez G, Maynar-Moliner J, Sanchez-Izquierdo-Riera JA, grupo FRAMI de la SEMI.CYUC (2006) Epidemiología del FRA en las UCI españolas: estudio prospectivo multicéntrico FRAMI. Med Intensiva 30:260–267

3. Bellomo R, Ronco C, Kellum JA, Metha RL, Palevsky P, ADQI workgroup (2004) Acute renal failure: definition, outcome, measures, animal models, fluid therapy and information technology needs: the second international consensus conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care 8:204–212

4. Bellomo R, Kellum JA, Ronco C (2004) Defining acute renal failure: physiological principles. Intensive Care Med 30:33–37

5. Seller-Pérez G, Herrera-Gutiérrez ME, Banderas-Bravo E, Muñoz-Bono J, Fernández-Ortega J, Lebrón-Gallardo M (2005) Validation of 2 hours sampling creatinine clearance in ICU population, included unstable patients. Intensive Care Med (Suppl) 31(1):S146

6. Levey AS, Bosh JP, Lewis JB, Green T, Rogers N, Roth D (1999) A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. Ann Intern Med 130:461–470

7. Vincent JL, Moreno R, Takala J, Willatts S, De Mendonça A, BruiningH, Reinhart CK,Suter PM,Thijs LG (1996) The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. Intensive Care Med 22:707–710

8. Menitz PG, Krenn CG, Steltzer H, Lang T, Ploder J, Lenz K, Le Gall JR, Drum WL (2002) Effect of acute renal failure requiring renal replacement therapy on outcome in critically ill patients. Crit Care Med 30:2051–2058

9. Ahlström A, Tallgren M, Peltonen S, Räsänen P, Pettilä V (2005) Survival and quality of life of patients requir.ing acute renal replacement therapy. Intensive Care Med 31:1222–1228

10. Andrews P, Azoulay E, Antonelli M, Brochard L, Brun-Buisson C, de Backer D, Dobb G, Fagon JY, Ger.lach H, Groeneveld J, Mancebo J, Metnitz P, Nava S, Pugin J, Pinsky M, Radermacher P, Richard C, Tasker R (2006) Year in review in intensive care medicine. 2005. I. Acute respira.tory failure and acute lung injury, ventilation, hemodynamics, education, renal failure. Intensive Care Med DOI 10.1007/s00134-005-0027-z

11. Hewitt SM, Dear J, Star RA (2004) Discovery of protein biomarkers for renal disease. J Am Soc Nephrol 15:1677–1689

12. Han WK, Bonventre JV (2004) Biologic markers for the early detection of acute kidney injury. Curr Opin Crit Care 10:476–482

13. Schrier RW, Wang W, Poole B, Mitra A (2004) Acute renal failure: definitions, diagnosis, pathogenesis, and therapy. J Clin Invest 114:5–14

14. Moran SM, Meyers BD (1985) Course of acute renal failure studied by a model of creatinine kinetics. Kidney Int 27:928–937

15. Lameire N, Hoste E (2004) Reflections on the definition, classification, and diagnostic evaluation of acute renal failure. Curr Opin Crit Care 10:468–475

16. Han WK, Bailly V, Abichandani R, Thadhani R. Bonventre JV (2002) Kidney injury molecule-1 (KIM-1): a novel biomarker for human renal proximal tubule injury. Kidney Int 62:237–244

17. Hoste EA, Damen J, Vanholder RC, Lameire NH, Delanghe JR, Van den Hauwe KV, Colardyn FA (2005) Assessment of renal function in recently admitted critically ill patients with normal serum creatinine. Nephrol Dial Transplant 20:747–753

18. Liu KD (2003) Molecular mechanisms of recovery from acute renal failure. Crit Care Med 31:S572–S581

19. Bell M, Liljestam E, Granath F, Fryckstedt J, Ekbom A, Martling CR (2005) Optimal follow-up time alter continuous replacement therapy in actual renal failure patients stratified with the RIFLE criteria. Nephrol Dial Transplant 20:354–360

20. Jelliffe R (2002) Estimation of creatinine clearance in patients with unstable renal function, without a urine specimen. Am J Nephrol 22:320–324

21. Cockroft DW, Gault MH (1976) Prediction of creatinine clearance from serum creatinine. Nephron 16:31–41

22. Kim KE, Onesti G, Ramirez O (1969) Creatinine clearance in renal disease: a reappraisal. BMJ 4:11–19

23. O'Connell MB, Wong MO, Bannick SD, Dwinell AM (1993) Accuracy of 2 and 8 hour urine collections for measuring creatinine clearance in the hospitalized elderly. Pharmacotherapy 13:135–142

24. Baumann TJ, Staddon JS, Horst HM, Bivins BA (1987) Minimum urine collections periods for accurate determinations of creatinine clearance in critically ill patients. Clin Pharm 6:393–398

25. Wilson RF, Soullier G (1980) The validity of two hour creatinine clearance studies in critically ill patients. Crit Care Med 8:281–284

26. Herget-Rosenthal S, Kribben A, Pietruck F, Ross B, Philipp T (1999) Two by two hour creatinine clearance: repeatable and valid. Clin Nephrol 51:348–354

27. Uchino S, Doig G, Bellomo R, Moti.matsu H, Morgera S, Schetz M, Tan I, Bouman C, Nacedo E, Gibney N, Tolwani A, Ronco C, Kellum JA, the Beginning and Ending Supportive

Therapy for the Kidney (BEST Kidney) investigators (2004) Diuretics and mortality in acute renal failure. Crit Care Med 32:1669–1677

28. Stevens LA, Coresh J, Greene T, Levey AS (2006) Assessing kidney function – measured and estimated glomerular filtration rate. N Engl J Med 354:2473–2483

29. Delanaye P, Lambermont B, Chapelle JP, Gielen J, Gerard P, Rorive G (2004) Plasmatic cystatin C for the estimation of glomerular filtration rate in intensive care units. Intensive Care Med 30:980–983

30. Villa P, Jiménez M, Soriano MC, Manzanares J, Casasnovas P (2005) Serum cystatin C concentration as a marker of acute renal dysfunction in critically ill patients. Critical Care 9:139–143

31. Herget-Rosenthal S, Marggaf G, Hus.ing J, Goring F, Pietruck F, Janssen O, Philipp T, Kribben A (2004) Early detection of acute renal failure by serum cystatin C. Kidney Int 66:1115–1122

32. Filler G, Foster J, Acker A, Lepage N, Akbari A, Ehrich JHH (2005) The Cockroft–Gault equation should not be used in children. Kidney Int 75:2321–2324

Table 1.
Events recorded and patient management during the study protocols

Perfusion 63 (17.5%)
Bolus 115 (32%)
Bolus in 2 hours 20 (5.6%)
Mannitol 54 (15%)
Diuretic dopamine 15 (4.2%)
NSAIDs 100 (27.9%)
Hyperglycemia 107 (29.8%)
Hypotension 71 (19.8%)
Vasopressors 106 (29.5%)
Irregular diuresis 199 (55.4%)
Oliguria day of study 9 (2.5%)
Oliguria in 2 hours 42 (11.7%)

Table 2
Effect of the study variables in relation to the CrCl-24 h–CrCl-2 h difference

	All patients	p	CrCl < 100	p
Male sex	–12.7 ± 3.3 (214)	< 0.001	0.1 ± 2.1 (104)	ns
Age > 65 years	–3.9 ± 2.5 (117)	ns	–0.6 ± 1.7 (84)	ns
Diabetes mellitus	–2.1 ± 4.1 (58)	ns	2.9 ± 3.1 (47)	ns
Hypertension	–4.1 ± 2.6 (108)	ns	–1.3 ± 2.3 (84)	ns
Liver disease	–3.9 ± 5.1 (32)	ns	1.2 ± 4.6 (20)	ns
Prior kidney dysfunction	–2.2 ± 3.8 (26)	ns	–2.2 ± 3.7 (26)	ns
Trauma patients	22.4 ± 8.1 (71)	ns = 0.06	17.4 ± 7.5 (9)	ns
Sepsis	9.6 ± 4.8 (37)	ns	0.5 ± 2.1 (28)	ns
Emergency surgery	9.8 ± 6.3 (36)	ns	2.9 ± 4.4 (26)	ns
Programmed surgery	3.2 ± 5.3 (58)	ns	–1.0 ± 4.6 (33)	ns
Liver transplant	2.4 ± 6.1 (23)	ns	–3.8 ± 5.1 (12)	ns
Other diagnosis	0.2 ± 3.8 (82)	ns	–1.2 ± 2.7 (58)	ns
Creatinine >1.2 mg/dl	–2.6 ± 3.7 (60)	ns	3.1 ± 2.3 (102)	ns
Oliguria <0.5 ml/kg/h	–0.2 ± 4.7 (7)	ns	0.9 ± 5.4 (6)	ns
Oliguria during 2 h	–16.7 ± 4.9 (34)	< 0.005	–8.6 ± 4.7 (25)	ns
Irregular diuresis	–4.7 ± 3.2 (170)	ns	1.9 ± 2.3 (97)	ns
Hypotension	–12.7 ± 4.2 (55)	< 0.005	3.9 ± 3.3 (30)	ns
Vasopressors	–9.8 ± 4.3 (89)	< 0.05	2.3 ± 2.7 (60)	ns
Hyperglycemia	–12.8 ± 4.3 (90)	< 0.001	2.7 ± 3.4 (60)	< 0.05
Furosemide	2.8 ± 2.4 (158)	ns	3.4 ± 1.9 (120)	ns
Bolus during 2 h	9.2 ± 10.1 (19)	ns	–8.3 ± 5.4 (11)	ns
Diuretic dopamine	–10.3 ± 5.9 (12)	ns	–0.9 ± 1.9 (8)	ns
Mannitol	–26.1 ± 9.9 (42)	< 0.001	1.1 ± 4.2 (11)	ns
Vancomycin	–2.9 ± 9.5 (22)	ns	13.9 ± 23.9 (13)	ns
NSAIDs	–9.2 ± 6.6 (87)	ns	–0.1 ± 4.3 (34)	ns

Data expressed as mean ± SEM (n); CrCl in ml/min/1.73 m2

Figure 1

Bland–Altman plot of the difference CrCl-24h versus CrCl-2h (top) and CrCl-24h versus Ck-G (bottom); The dashed lines represent two times the standard deviation

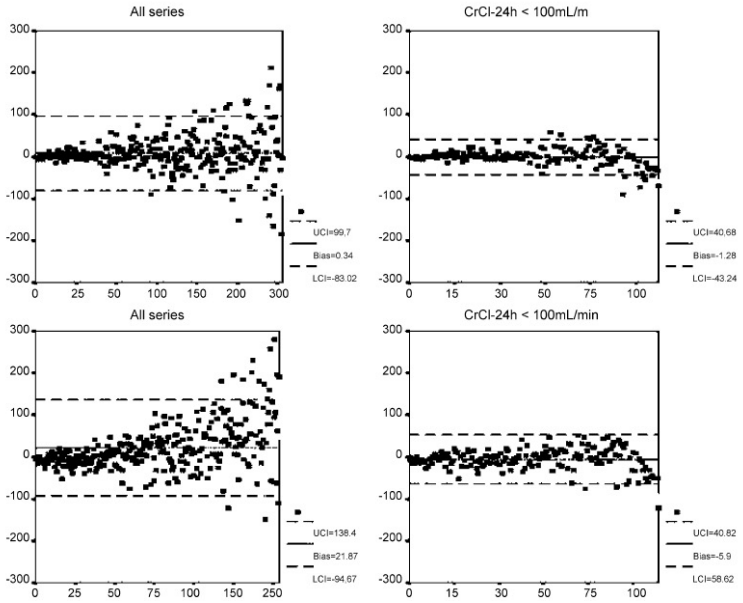

Fig. 2

Usefulness of 1/serum creatinine, Cockroft–Gault equation and 2-h creatinine clearance for the diagnosis of kidney injury (de.fined as 24-h creatinine clearance < 60 ml/min/1.73 m2)

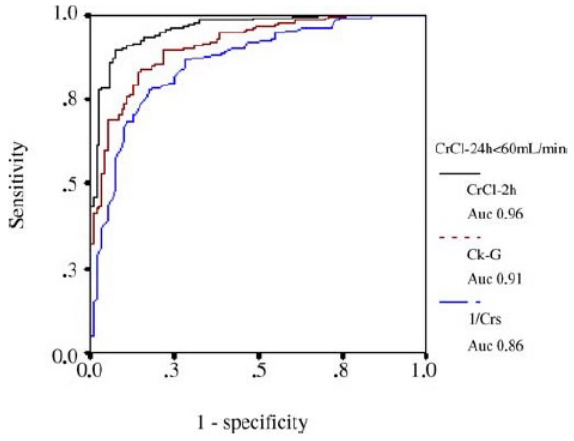

Fig. 3

Correlations between CrCl-24h and CrCl-2h (top) and between CrCl-24h and Ck-G (bottom)