

Research article

Association of Systemic Inflammation Index and Body Mass Index With Survival in Patients With Renal Cell Cancer Treated With Nivolumab

Running title: Association of SII and BMI With Survival to Nivolumab in RCC

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Disclosure of Potential Conflicts of Interest

U. De Giorgi plays a consultant/advisory role in BMS, Ipsen, Pfizer, Novartis, Merck, Astellas, Janssen, Sanofi, Bayer; G. Procopio received honoraria for advisory role from Bayer, BMS, Eisai, Ipsen, MSD, Novartis, Roche, Pfizer; R. Sabbatini plays a consultant/advisory role in BMS, Ipsen, Pfizer, Novartis, Astellas, Janssen, Sanofi; A. Bearz received speaker honoraria and travels from Boehringer Ingelheim, Takeda, Roche, Novartis, Pfizer, Eli-Lilly, BMS, MSD; U. Basso received speaker fees from BMS, Pfizer, Novartis, Janssen, Astellas, Sanofi, and advisory role from MSD, Janssen, Incyte; P. Bidoli plays a consultant/advisory role in Eli-Lilly, BMS, Boehringer; C. Caserta received speaker fee from Pfizer and consultant/advisory role from Novartis, BMS, Ipsen, MSD; C. N. Sternberg received honoraria from BMS, Novartis, Pfizer, Ipsen Consultancy: Eisai, Pfizer, Ipsen, BMS, Roche, Bayer, MSD and Institutional funding at San Camillo Hospital Rome: Eisai, Pfizer, Argos, Aveo, AstraZeneca, BMS, Exelixis, GSK, Millennium, Nektar.

Translational Relevance (122 words)

Inflammation indexes associated with body mass index (BMI) are risk factors associated with survival of patients with metastatic renal cell carcinoma (RCC) treated with VEGF-targeted therapies. We investigated whether lower BMI and higher inflammatory indexes combining neutrophils (N), platelets (P) and lymphocytes (L), as NLR (N/L), PLR (P/L) and SII (NxP/L) are associated with overall survival in metastatic RCC treated with nivolumab. In a cohort of 313 patients with metastatic RCC, age younger than 70 years, elevated SII and normal BMI were independently associated with poor overall survival. Because BMI and SII are commonly collected and potentially modifiable, they have a high potential for clinical use in determining prognosis and may help guide interventions to optimize survival with nivolumab in metastatic RCC.

Abstract (max 250 words)

Purpose: Inflammation indexes and body mass index (BMI) are easily evaluated, predict survival and are potentially modifiable. We evaluated the potential association of inflammatory indexes and BMI with the clinical outcome of patients with renal cell carcinoma (RCC) undergoing immune checkpoint inhibitor therapy.

Experimental design: A prospective cohort of patients with metastatic RCC treated with nivolumab enrolled in the Italian Expanded Access Program (EAP) from July 2015 through April 2016 was examined. Reference measures of inflammation were identified for neutrophil to lymphocyte ratio (NLR) ≤ 3 , systemic immune-inflammation index (SII) ≤ 1375 and platelet to lymphocyte ratio (PLR) ≤ 232 . Patients were classified as high BMI (≥ 25 kg/m²) versus normal BMI (< 25 kg/m²).

Results: Among 313 evaluable patients, 235 (75.1%) were male, median age was 65 years (range, 40 to 84), with 105 (33.69%) ≥ 70 years. In univariate analysis, age, performance status, BMI, SII, NLR and PLR were able to predict outcome. In multivariate analyses, SII ≥ 1375 , BMI < 25 and age ≥ 70 years independently predicted OS (HR, 2.96; 95% CI, 2.05-4.27; HR, 1.59; 95% CI, 1.10-2.30 and HR, 1.65; 95% CI, 1.07-2.55, respectively). A patient with both SII ≥ 1375 and BMI < 25 was estimated to have much worse OS (HR, 3.37; 95% CI, 2.29-4.95, $P < 0.0001$) than a patient with neither or only one risk factor. SII changes at 3 months predicted OS ($P < 0.0001$).

Conclusions: Normal BMI combined with inflammation tripled the risk of death, suggesting that these biomarkers are critical prognostic factors for OS in patients with RCC treated with nivolumab.

Introduction

Nivolumab is a monoclonal antibody that targets programmed death-1 receptor (PD-1). It has been approved as monotherapy for the treatment of patients with advanced renal cell carcinoma (RCC) progressing after prior antiangiogenic therapy (1). Biomarkers predicting clinical outcome with nivolumab would allow early identification of non-responders and timely use of other therapies.

Two novel prognostic indicators are receiving increasing attention across many cancer types and RCC in particular. These are body mass index (BMI) and an elevated neutrophil to lymphocyte ratio (NLR, a measure of systemic inflammation). Obesity is an established risk factor for RCC and is associated with a better prognosis in these patients (2). The potential correlation between high BMI and more favorable treatment outcome to vascular endothelial growth factor (VEGF)-targeted therapy in metastatic RCC has also been shown (3, 4). The role of blood cell count indexes as possible biomarkers of response and efficacy has been recently investigated. NLR is the most tested prognostic index and has been associated with prognosis in several tumors including RCC treated with antiangiogenic agents (5-10). Thrombocytosis and lymphopenia have also been associated with prognosis in metastatic RCC treated with first-line VEGF-targeted treatment (11, 12). Systemic immune-inflammation index (SII) combines these three parameters: neutrophils, platelets and lymphocytes, and has been previously significantly associated with prognosis in several tumor types including metastatic RCC (13-15).

Both inflammation and BMI may be able to identify patients with poor prognosis to VEGF-targeted therapies, but the relationship between these factors and their independent associations with survival are not well studied. Recent trials underscore the importance of systemic inflammation as a driver of muscle degradation in patients with far advanced disease, but other studies have suggested that similar processes may occur in patients with localized disease. Elevated inflammatory indexes as NLR were present in nearly half of patients and were associated with decreased BMI as predictive of poorer survival even in patients with non-metastatic colorectal

cancer (16, 17). In RCC, the "obesity paradox" of longer survival in patients with high BMI has been explained by altered fatty acid pathways in obese relative to normal weight patients with marked downregulation of fatty acid synthase, which could have an impact in immune-inflammatory function with potential impact on cancer survival (4, 18, 19).

To our knowledge, no prior study has examined the combined associations of the host systemic inflammatory response and BMI with RCC survival. Moreover, no prior study has evaluated the potential association of BMI and inflammatory indexes with clinical outcome of patients undergoing immune checkpoint inhibitor therapy. Accordingly, we conducted an analysis to determine whether pretreatment inflammatory indexes and BMI could predict clinical outcome to nivolumab using data from patients with metastatic RCC enrolled in the Italian Expanded Access Program (EAP). Subsequently, we assessed the independent and combined associations of these two prognostic indicators with survival.

Methods

Study cohort

The purpose of the EAP was to provide nivolumab to patients with RCC who had progressed on VEGF-targeted treatment while the drug was evaluated by the EMA. Key inclusion criteria were histologically confirmed metastatic RCC, Eastern Cooperative Oncology Group (ECOG) performance status ≤ 2 , at least one prior VEGF-targeted therapy in the advanced setting, presence of asymptomatic brain metastases was accepted. Patients with active or suspected autoimmune disease were excluded. Treatment consisted of nivolumab 3 mg/kg every 2 weeks until unacceptable toxicity, disease progression, or patient choice. The study protocol was reviewed and approved by local Ethics Committees and in accordance with the precepts established by the Declaration of Helsinki. Written informed consent was obtained from all study participants. All data were prospectively collected on electronic patient files.

From July 2015 to April 2016, 389 patients were treated with at least one dose of nivolumab in the EAP in Italy. Of these, 313 (80.5%) had baseline complete blood counts necessary for the inflammatory indexes and all clinical data available and were considered fully evaluable for this post hoc analysis.

Post hoc analysis variable definitions

For this post hoc analysis, three inflammatory indexes were determined based on baseline values of neutrophils (N), lymphocytes (L), and/or platelets (P) in patients with metastatic RCC included in the EAP: SII defined as $P \times N/L$, NLR defined as N/L , platelet-lymphocyte ratio (PLR) defined as P/L . X-tile 3.6.1 software was used to determine the most appropriate discriminatory cutoff values for SII, NLR and PLR for the analysis (13). The cut-offs were selected as the values that maximize differences between overall survival (OS) in the two groups identified (below and above the cut-off). We selected the height and weight obtained closest to beginning of nivolumab treatment to calculate the BMI defined as the ratio of weight divided by the height squared. Patients were classified into BMI groups defined by the World Health Organization: underweight (BMI <18.5 kg/m²), normal weight (BMI, 18.5 to <25 kg/m²), overweight (BMI, 25 to <30 kg/m²), and obese (BMI ≥ 30 kg/m²) and condensed to high BMI (≥ 25 kg/m²) versus normal BMI (<25 kg/m²).

Statistical analysis

Data were presented by absolute frequency and percentage for categorical variables and by median and range for continuous variables (e.g. age). Association between categorical variables was assessed using the chi square test. Differences were considered statistically significant when $P < 0.05$. The primary clinical outcome was OS. OS was defined as the time period between nivolumab initiation and the date of death, or it was censored on the day of the last follow-up visit. Objective response rate (ORR) was defined as the proportion of patients who achieved a complete or partial response in all evaluated patients. Disease control rate (DCR) was defined as the proportion of

patients who achieved a complete or partial response or stable disease in all evaluated patients. The Kaplan-Meier method was used to estimate OS and the log-rank test was used to assess differences between survival. Cox proportional hazards regression model was used to estimate hazard ratios and their 95% confidence intervals. A multivariate analysis was carried out considering only factors significant at the univariate analysis and based on a stepwise forward procedure with enter and remove limits of 0.05 and 0.10, respectively.

The impact of change on survival outcomes was evaluated by the landmark analysis at 3 months. For this analysis, patients with early disease progression/death or patients lost to follow-up before the landmark time were excluded. All statistical analyses were conducted by an experienced biostatistician with SPSS Statistical Software, version 21.0, Armonk, NY, USA.

Results

Patient characteristics

Three hundred thirteen cases were considered for this analysis, with a median age before starting nivolumab of 65 years (range, 40 to 84), 235 (75.1%) male. The histotype was clear cell RCC in 280 (89.5%) cases. Only 69 (22.1%) patients received nivolumab as second-line therapy after a VEGF-targeted treatment, most cases received nivolumab as third-line (n=107, 34.3%) or further line of therapy (n=136, 43.6%). Baseline clinical characteristics are shown in Table 1. An optimal cutoff point for the SII of 1375×10^9 stratified these patients into high (≥ 1375 , n=96, 30.7%) and low SII (< 1375 , n=217, 69.3%) groups, cut-off for NLR was 3 and categorized as high (≥ 3 , n=195, 62.3%) and low NLR (< 3 , n=118, 37.7%), for PLR was 232 with high (≥ 232 , n=108, 34.5%) and low PLR (< 232 , n=205, 65.5%). Normal BMI < 25 kg/m² was reported in 50.2% of patients, high BMI ≥ 25 kg/m² in 49.8%. The percentage of cases with BMI $<$ or ≥ 25 kg/m² was independent from the line of therapy.

Systemic inflammation, BMI and response

In the overall population of 313 cases, a ORR was reported in 70 of 286 (24.5%) assessable patients, including complete response in 1 (0.4%) cases, partial response in 69, (24.1%), respectively; stable disease was reported in 106 cases (37.1%) and progressive disease in 110 (38.4%), whereas in the remaining 27 cases (8.6%) the tumor response was not assessed, in the majority of cases because of clinical deterioration before the first CT scan evaluation. Lower ORR were associated with higher values of inflammatory indexes at baseline, and these results were consistent across all markers of systemic inflammation.

The ORR for patients with SII <1375 was 29% (60 of 207 cases), whereas those with SII \geq 1375 was only 13% (10 of 79 cases), ($P = 0.004$). The ORR for patients with NLR <3 was 27% (31 of 114 cases), whereas those with NLR \geq 3 was 23% (39 of 172 cases), ($P = 0.38$). The ORR for patients with PLR <232 was 29% (56 of 196 cases), whereas those with PLR \geq 232 was 16% (14 of 90 cases), ($P = 0.02$). The ORR in patients with normal BMI <25 was 24% (32 of 132 evaluable cases), whereas those with high BMI \geq 25 was 27% (37 of 136 evaluable cases), ($P = 0.58$). The DCR for patients with SII <1375 was 68% (141 of 207 cases), whereas those with SII \geq 1375 was only 41% (32 of 79 cases), $P < 0.0001$. The DCR for patients with NLR <3 was 64% (73 of 114 cases), whereas those with NLR \geq 3 was 60% (103 of 172 cases), $P = 0.50$. The DCR for patients with PLR <232 was 68% (133 of 196 cases), whereas those with PLR \geq 232 was 35% (32 of 90 cases), $P < 0.0001$. The DCR in patients with normal BMI <25 was 58% (76 of 132 evaluable cases), whereas those with high BMI \geq 25 was 67% (91 of 136 evaluable cases), $P = 0.13$.

Baseline high inflammatory indexes were associated with IMDC prognostic factors, but no with histotypes and metastatic sites (Table 2)

Survival analysis

Univariate and multivariate Cox proportional hazards regression analyses were performed to assess the associations between factors of interest and OS. In univariate analysis, the following clinical variables predicted OS: age, performance status and BMI; whereas among the blood cell

count variables, neutrophil and platelets, but not lymphocytes predicted outcome; in addition, all three blood cell count indexes (SII, NLR and PLR) were able to predict outcome (Table 2). As observed in the Kaplan-Meier curves, patients with normal BMI, those with $SII \geq 1375$ and <70-year-old patients had the worst survival (Figure 1 A, B and C). Moreover, we analyzed BMI as a continuous variable and correlated with OS (HR, 0.93; 95% CI, 0.88-0.99), $P = 0.02$), showing that an increase of the weight is directly correlated with better prognosis.

In multivariate analyses, $SII \geq 1375$, BMI <25 and age ≥ 70 years independently predicted OS (HR, 2.96; 95% CI, 2.05-4.27; HR, 1.59; 95% CI, 1.10-2.30 and HR, 1.65; 95% CI, 1.07-2.55, respectively) (Table 3). Under the model of independent effects, a patient with both $SII \geq 1375$ and BMI <25 was estimated to have much worse OS (HR, 3.37; 95% CI, 2.29-4.95, $P < 0.0001$) than a patient with neither or only one risk factor.

When the SII groups (<1375 or ≥ 1375) were analyzed according to the BMI (<25 or ≥ 25), the four groups were as follows: 1) SII <1375 and BMI <25 in 94 (32.3%) cases, 2) SII <1375 and BMI ≥ 25 in 111 (38.1%), 3) SII ≥ 1375 and BMI ≥ 25 in 35 (12.0%), 4) SII ≥ 1375 and BMI <25 in 51 (17.5%). Figure 2 shows the OS according to these four groups.

The change of the three inflammatory indexes over time was evaluable in 260 (83.1%) of 313 cases at one time point of the follow-up after 2-3 months. Patients with baseline SII <1375 with follow-up SII ≥ 1375 were estimated to have a worse OS than those with follow-up SII <1375, $P < 0.0001$ as well as patients with baseline SII ≥ 1375 with follow-up SII ≥ 1375 were estimated to have a worse OS than those with follow-up SII <1375, $P = 0.05$. Patients with baseline NLR <3 with follow-up NLR ≥ 3 were estimated to have a worse OS than those with follow-up NLR <3, $P = 0.02$ as well as patients with baseline NLR ≥ 3 with follow-up NLR ≥ 3 were estimated to have a worse OS than those with follow-up NLR <3, $P = 0.002$. Patients with baseline PLR <232 with follow-up PLR ≥ 232 were estimated to have a worse OS than those with follow-up PLR <232, $P = 0.001$ as well as patients with baseline PLR ≥ 232 with follow-up PLR ≥ 232 were estimated to have a worse

OS than those with follow-up PLR <232 , $P = 0.03$. Table 4 shows the PFS and OS according to SII changes.

Discussion

The efficacy of immune check-point inhibitors in metastatic RCC varies greatly across individual patients and among different histotypes. Whereas PD-L1 expression on the primary tumor is now accepted as a potential biomarker indicating the use of these monoclonal antibodies as a front-line approach, no substantial results have been reported with clinical and molecular biomarkers for nivolumab used as second or greater line of treatment in metastatic RCC (1). We previously conducted an analysis of the Italian RCC EAP, which showed that efficacy and safety of nivolumab for the treatment of metastatic RCC were comparable to phase 3 results, OS, PFS and ORR in our cohort were similar to the observations in the CheckMate 025 studies (1, 20).

In this analysis, we showed that for metastatic RCC patients treated with nivolumab, higher SII was independently associated with worse outcomes in terms of reduced ORR, DCR and shorter OS, whereas a relative increase of BMI was associated with better OS, and the combination of these two factors (high SII with normal BMI) nearly tripled the risk of death, suggesting that these biomarkers are prognostic factors for OS in patients with metastatic RCC treated with nivolumab. We also showed that high levels of inflammatory parameters at 2- or 3-month follow-up were associated with OS, in particular SII changes showed a stronger impact on OS (Table 4). Further studies should investigate SII changes over time associated with changes on the radiological response and the clinical outcome of these patients.

Interestingly, the results seen at univariate analysis confirmed the pre-treatment impact on OS of neutrophils and platelets, but not lymphocytes, as already demonstrated in the International mRCC Database Consortium (IMDC) prognostic classification (12, 21). As expected, high inflammatory indexes were associated with IMDC prognostic factors (Table 2), however the IMDC prognostic score did not remain significant at multivariate analysis (Table 3). Among the three derived indexes

NLR, PLR and SII, only SII remained significant at multivariate analysis, as a consequence of using both neutrophil and platelet levels. Taken together these data confirm the prognostic role of platelets and neutrophils and suggest the combined index SII as the strongest inflammatory index for metastatic RCC. Our findings are consistent with and build upon previous reports evaluating NLR in RCC patients treated with nivolumab (22-24), but suggest that SII appears superior to NLR as an inflammatory, readily-available, prognostic marker in metastatic RCC patients treated with immune check-point inhibitors in metastatic RCC, and warrants further larger prospective validation.

BMI has been already shown to be a robust biomarker for outcomes in RCC both in the preoperative localized disease and in the metastatic VEGF-targeted treated population (2-4). In our experience, BMI was associated with OS but not with either ORR ($P = 0.58$) or DCR ($P = 0.13$); as such it may be speculated that BMI represents a simple biomarker for "better RCC". However, improved OS in obese cancer patients compared with those with normal BMI, has been recently observed also in melanoma patients treated with immune checkpoint inhibitors (25). In addition, these clinical findings are corroborated by preclinical data indicating that obesity increases T cell aging resulting in higher PD-1 expression and dysfunction, which is driven by leptin signaling, this effect leaves tumors notably more sensitive to checkpoint blockade (26).

Patient age and gender are arising as potential prognostic/predictive factors for immunotherapy response. In melanoma, older patients ≥ 60 years responded more efficiently to anti-PD-1 agents, and the ORR to these drugs increased with age (27). In RCC, elderly patients ≥ 70 years were associated with increased ORR of nearly 30% higher than the nearly 20% reported in younger patients (820). Results of a meta-analysis of twenty randomized clinical trials with immune check-point inhibitors in solid tumors suggest that males derive more benefit than females, even if only the CheckMate 025 trial included patients with RCC and the hazard ratio was unadjusted for other confounding factors (28). Moreover, a recent large retrospective analysis of the IMDC has shown that gender has no impact on the efficacy of nivolumab (29). Results of the multivariate analysis of

the present study, confirmed the positive prognostic impact of older age (≥ 70 years) of RCC patients, whereas it did not show any impact based on gender (Table 3), suggesting that the conclusions of the above-mentioned meta-analysis may not be generalizable to the setting of RCC. Median values of BMI in healthy people is approximately 24.5 kg/m² for men and 21.5 kg/m² for women (30), thus a possible explanation of the marginal advantage of male gender on the efficacy of nivolumab in the CheckMate 025 trial could be also due to the higher BMI in males than females (1, 28). However, in the recent retrospective study in patients with metastatic melanoma, obesity, compared with normal BMI, has been associated with improved PFS and OS in patients treated with immunotherapy (pembrolizumab or nivolumab or atezolizumab, total of 331 cases), and this association has been mainly observed in male patients (255). Future research should consider BMI exploring the effectiveness of immunotherapies in men and women.

An unmet need is the development of biomarkers of clinical outcome to immune-check point inhibitors in order to identify patients who are likely to respond and obtain clinical benefit from such treatments. This aspect is particularly relevant for tumors with low response rates, such as metastatic RCC treated with nivolumab which has response rates ≤ 25 -30%, but long-term survival of more than four years in 20-25% of cases (31, 32).

To our knowledge, this is the first study to examine the relationship between biomarkers of systemic inflammation and BMI in RCC, and the only study to examine whether inflammatory indexes and BMI are independently associated with OS in metastatic RCC. As in any retrospective analyses, in our study several potential biases should be considered. In addition, other limitations are the use of BMI as the only morphometric parameter, because it does not provide information on muscle mass and fat repartition, and lacks metabolic biomarkers. Finally, lack of a validation cohort is a concern, however our data refer to a late use of nivolumab, mostly in third or fourth line (Table 1), whereas the current use is mainly in second-line and in the first-line with the combination of nivolumab plus ipilimumab (1, 33). Therefore, our findings should be considered only hypothesis

generating and require additional validation in larger series with immune check-point inhibitors in earlier therapeutic settings.

In conclusion, SII, BMI and older age of patients were independent prognostic factors in metastatic RCC treated with nivolumab. SII and BMI are routinely collected in clinical practice and thus deserve a potential role for use as prognostic indices, if these findings are confirmed by further studies. We also found that the co-occurrence of normal BMI and high inflammatory indexes identified patients with a more than 3-fold risk of mortality compared with patients with neither condition. A better understanding of biological mechanisms may help to guide interventions to optimize survival outcomes with nivolumab in metastatic RCC. Further studies are needed to clarify whether reducing systemic inflammation or possibly increasing low BMI with supportive care can enhance OS outcomes exploring the effectiveness of nivolumab in men and women. The mechanisms that are responsible for these findings will potentially be of great interest.

Authors' Contributions

Conception and design: U. De Giorgi, G. Procopio, C.N. Sternberg

Development of methodology: U. De Giorgi, D. Giannarelli, C.N. Sternberg

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References

1. Motzer RJ, Escudier B, McDermott DF, George S, Hammers HJ, Srinivas S, et al. Nivolumab versus everolimus in advanced renal-cell carcinoma. *N Engl J Med* 2015;373:1803-13.
2. Choi Y, Park B, Jeong BC, Seo SI, Jeon SS, Choi HY, et al. Body mass index and survival in patients with renal cell carcinoma: a clinical-based cohort and meta-analysis. *Int J Cancer* 2013;132:625-34.
3. Steffens S, Grünwald V, Ringe KI, Seidel C, Eggers H, Schrader M, et al. Does obesity influence the prognosis of metastatic renal cell carcinoma in patients treated with vascular endothelial growth factor-targeted therapy? *Oncologist* 2011;16:1565–71.
4. Albiges L, Hakimi AA, Xie W, McKay RR, Simantov R, Lin X, et al. Body mass index and metastatic renal cell carcinoma: clinical and biological correlations. *J Clin Oncol* 2016;34:3655-63.
5. Templeton AJ, McNamara MG, Šeruga B, Vera-Badillo FE, Aneja P, Ocaña A, et al. Prognostic role of neutrophil-to-lymphocyte ratio in solid tumors: a systematic review and meta-analysis. *J Natl Cancer Inst* 2014;106:dju124.

6. Keizman D, Gottfried M, Ish-Shalom M, Maimon N, Peer A, Neumann A, et al. Pretreatment neutrophil-to-lymphocyte ratio in metastatic castration-resistant prostate cancer patients treated with ketoconazole: association with outcome and predictive nomogram. *Oncologist*. 2012;17:1508-14.
7. Rossi L, Santoni M, Crabb SJ, Scarpi E, Burattini L, Chau C, et al. High neutrophil-to-lymphocyte ratio persistent during first-line chemotherapy predicts poor clinical outcome in patients with advanced urothelial cancer. *Ann Surg Oncol* 2015; 22:1377–84.
8. Passardi A, Scarpi E, Cavanna L, Dall'Agata M, Tassinari D, Leo S, et al. Inflammatory indexes as predictors of prognosis and bevacizumab efficacy in patients with metastatic colorectal cancer. *Oncotarget* 2016;7:33210-9.
9. Keizman D, Ish-Shalom M, Huang P, Eisenberger MA, Pili R, Hammers H, Carducci MA. The association of pre-treatment neutrophil to lymphocyte ratio with response rate, progression free survival and overall survival of patients treated with sunitinib for metastatic renal cell carcinoma. *Eur J Cancer* 2012;48:202-8.
10. Santoni M, De Giorgi U, Iacovelli R, Conti A, Burattini L, Rossi L, et al. Pre-treatment neutrophil-to-lymphocyte ratio may be associated with the outcome in patients treated with everolimus for metastatic renal cell carcinoma. *Br J Cancer* 2013;109:1755–9.
11. De Giorgi U, Rihawi K, Aieta M, Lo Re G, Sava T, Masini C, et al. Lymphopenia and clinical outcome of elderly patients treated with sunitinib for metastatic renal cell cancer. *J Geriatr Oncol* 2014;5:156–63.
12. Heng DY, Xie W, Regan MM, Harshman LC, Bjarnason GA, Vaishampayan UN, et al. External validation and comparison with other models of the International Metastatic Renal-Cell Carcinoma Database Consortium prognostic model: a population-based study. *Lancet Oncol* 2013;14:141–8.

13. Hu B, Yang XR, Xu Y, Sun YF, Sun C, Guo W, et al. Systemic immune inflammation index predicts prognosis of patients after curative resection for hepatocellular carcinoma. *Clin Cancer Res* 2014;20:6212–22.
14. Lolli C, Caffo O, Scarpi E, Aieta M, Conteduca V, Maines F, et al. Systemic immune-inflammation index predicts the clinical outcome in patients with mCRPC treated with abiraterone. *Front Pharmacol* 2016;7:376.
15. Lolli C, Basso U, Derosa L, Scarpi E, Sava T, Santoni M, et al. Systemic immune-inflammation index predicts the clinical outcome in patients with metastatic renal cell cancer treated with sunitinib. *Oncotarget* 2016; 7:54564-71.
16. Kroenke CH, Neugebauer R, Meyerhardt J, Prado CM, Weltzien E, Kwan ML, et al. Analysis of body mass index and mortality in patients with colorectal cancer using causal diagrams. *JAMA Oncol* 2016;2:1137-45.
17. Cespedes Feliciano EM, Kroenke CH, Meyerhardt JA, Prado CM, Bradshaw PT, Kwan ML, et al. Association of systemic inflammation and sarcopenia with survival in nonmetastatic colorectal cancer: results from the C SCANS study. *JAMA Oncol* 2017;3:e172319.
18. Ho PC, Liu PS. Metabolic communication in tumors: a new layer of immunoregulation for immune evasion. *J Immunother Cancer* 2016;4:4.
19. Biswas SK. Metabolic reprogramming of immune cells in cancer progression. *Immunity* 2015;43:435-49.
20. De Giorgi U, Carteni G, Giannarelli D, Basso U, Galli L, Cortesi E, et al. Safety and efficacy of nivolumab for metastatic renal cell carcinoma: real-world results from an expanded access program. *BJU Int* 2019;123:98-105.
21. Ko JJ, Xie W, Kroeger N, Lee JL, Rini BI, Knox JJ, et al. The International Metastatic Renal Cell Carcinoma Database Consortium model as a prognostic tool in patients with metastatic renal cell carcinoma previously treated with first-line targeted therapy: a population-based study. *Lancet Oncol* 2015;16:293-300.

22. Templeton AJ, Knox JJ, Lin X, Simantov R, Xie W, Lawrence N, et al. Change in neutrophil-to-lymphocyte ratio in response to targeted therapy for metastatic renal cell carcinoma as a prognosticator and biomarker of efficacy. *Eur Urol* 2016;70):358-64.
23. Bilen MA, Dutcher GMA, Liu Y, Ravindranathan D, Kissick HT, Carthon BC, et al. Association between pretreatment neutrophil-to-lymphocyte ratio and outcome of patients with metastatic renal-cell carcinoma treated with nivolumab. *Clin Genitourin Cancer* 2018;16(3):e563-e575.
24. Lalani AA, Xie W, Martini DJ, Steinharter JA, Norton CK, Krajewski KM, et al. Change in neutrophil-to-lymphocyte ratio (NLR) in response to immune checkpoint blockade for metastatic renal cell carcinoma. *J Immunother Cancer* 2018;6:5.
25. Kugel CH 3rd, Douglass SM, Webster MR, Kaur A, Liu Q, Yin X, et al. Age correlates with response to anti-PD1, reflecting age-related differences in intratumoral effector and regulatory T-cell populations. *Clin Cancer Res* 2018;24:5347-56.
26. McQuade JL, Daniel CR, Hess KR, Mak C, Wang DY, Rai RR, et al. Association of body-mass index and outcomes in patients with metastatic melanoma treated with targeted therapy, immunotherapy, or chemotherapy: a retrospective, multicohort analysis. *Lancet Oncol* 2018;19:310-22.
27. Wang Z, Aguilar EG, Luna JI, Dunai C, Khuat LT, Le CT, et al. Paradoxical effects of obesity on T cell function during tumor progression and PD-1 checkpoint blockade. *Nat Med* 2019;25:141-51.
28. Conforti F, Pala L, Bagnardi V, De Pas T, Martinetti M, Viale G, et al. Cancer immunotherapy efficacy and patients' sex: a systematic review and meta-analysis. *Lancet Oncol* 2018;19:737-46.
29. Graham J, Abdel-Rahman O, Choueiri TK, Heng DYC. Re: Fabio Conforti, Laura Pala, Vincenzo Bagnardi, et al. Cancer Immunotherapy Efficacy and Patients' Sex: A Systematic Review and Meta-analysis. *Lancet Oncol* 2018;19:737-46: Outcomes of Metastatic Renal Cell

Carcinoma by Gender: Contrasting Results from the International mRCC Database Consortium. *Eur Urol* 2018;74:e139-e140.

30. Flegal KM. Body mass index of healthy men compared with healthy women in the United States. *Int J Obes* 2006;30:374-9.
31. Motzer RJ, Rini BI, McDermott DF, Redman BG, Kuzel TM, Harrison MR, et al. Nivolumab for metastatic renal cell carcinoma: results of a randomized phase II trial. *J Clin Oncol* 2015;33:1430-7.
32. McDermott DF, Drake CG, Sznol M, Choueiri TK, Powderly JD, Smith DC, et al. Survival, durable response, and long-term safety in patients with previously treated advanced renal cell carcinoma receiving nivolumab. *J Clin Oncol* 2015;33: 2013-20.
33. Motzer RJ, Tannir NM, McDermott DF, Arén Frontera O, Melichar B, Choueiri TK, et al. Nivolumab plus ipilimumab versus sunitinib in advanced renal-cell carcinoma. *N Engl J Med* 2018;378:1277-90.

Table 1. Patient characteristics at baseline (N = 313).

Characteristics	N (%)
Age in years, median (range) ≥70 years, n (%)	65 (40–84) 105 (33.6%)
Gender, male/female	235/78
ECOG performance status, 0 1 2 NA	143 (47.2%) 146 (48.2%) 14 (4.6%) 10
IMDC prognostic group, Favourable (0 risk factors) Intermediate (1-2 risk factors) Poor (≥3 risk factors) NA	53 (19.0%) 194 (69.8%) 31 (11.2%) 35
Nephrectomy,	295 (94.3%)
Histology, Clear cell Non-clear cell Undifferentiated/Unknown	280 (89.5%) 28 (8.9%) 5 (1.6%)
Metastasis site, Lung Lymph node Bone Liver Brain	230 (73.5%) 193 (61.7%) 154 (49.2%) 106 (33.9%) 30 (9.6%)
Number of prior therapy lines, 1 2 ≥3 NA	69 (22.1%) 107 (34.3%) 136 (43.6%) 1
Hemoglobin level (mg/dL), ≥12 <12	139 (44.4%) 174 (55.6%)
BMI, <18.5 Normal, 18.5 to <25 Overweight, 25 to <30 Obese, ≥30 NA	7 (2.4%) 140 (47.8%) 111 (37.9%) 35 (11.9%) 20

Abbreviations: ECOG, Eastern Cooperative Oncology Group; NA, not available; IMDC, International Metastatic renal cell carcinoma Database Consortium; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

Table 2. Association between baseline high inflammatory indexes and IMDC prognostic factors, histotypes and metastatic sites.

	N. pts	SII > 1375, <i>P</i>	NLR > 3, <i>P</i>	PLR > 232, <i>P</i>
IMDC prognostic score				
Favourable (0 risk factors)	53	1 (2%)	21 (40%)	8 (15%)
Intermediate (1-2 risk factors)	194	58 (30%)	124 (64%)	68 (35%)
Poor (≥ 3 risk factors)	31	26 (84%) <i>P</i> < 0.0001	27 (87%) <i>P</i> = 0.0005	21 (68%) <i>P</i> < 0.0001
Bone metastases	159	43 (27%)	96 (60%)	52 (33%)
No	154	52 (34%)	100 (65%)	55 (36%)
Yes		<i>P</i> = 0.18	<i>P</i> = 0.36	<i>P</i> = 0.58
Brain metastases				
No	283	81 (29%)	179 (63%)	92 (32%)
Yes	30	14 (47%) <i>P</i> = 0.04	17 (57%) <i>P</i> = 0.52	15 (50%) <i>P</i> = 0.05
Lung metastases				
No	83	22 (26%)	53 (64%)	25 (30%)
Yes	230	73 (32%) <i>P</i> = 0.31	143 (62%) <i>P</i> = 0.75	82 (36%) <i>P</i> = 0.32
Liver metastases				
No	207	60 (29%)	131 (63%)	73 (35%)
Yes	106	35 (33%) <i>P</i> = 0.47	65 (61%) <i>P</i> = 0.73	34 (32%) <i>P</i> = 0.60
Lymph node metastases				
No	120	31 (26%)	75 (62%)	35 (29%)
Yes	193	64 (33%) <i>P</i> = 0.19	121 (63%) <i>P</i> = 0.86	72 (37%) <i>P</i> = 0.15
Clear cell histotype				
No	33	11 (33%)	18 (54%)	14 (42%)
Yes	280	84 (30%) <i>P</i> = 0.72	178 (64%) <i>P</i> = 0.26	93 (33%) <i>P</i> = 0.30

Abbreviations: IMDC, International mRCC Database Consortium; SII systemic inflammatory index; NLR, neutrophil-lymphocyte ratio; PLR, platelets-lymphocyte ratio.

Table 3. Univariate and multivariate analyses of the association between baseline characteristics and overall survival.

	Univariate analysis HR (95% CI), P	Multivariate analysis HR (95% CI), P
Age (<70 vs ≥70)	1.66 (1.12, 2.44), P = 0.01	1.62 (1.05, 2.50), P = 0.03
Gender (male vs female)	1.34 (0.88-2.03), P = 0.17	--
ECOG PS (1 vs 0) (2 vs 0)	1.41 (0.99-2.02), P = 0.06 2.28 (1.03-5.03), P = 0.04	--
IMDC prognostic groups (1-2 vs 0) (≥3 vs 0)	1.92 (1.06-3.47), P = 0.03 4.25 (2.11-8.56), P < 0.0001	--
Clear cell (no vs yes)	1.23 (0.62-2.43), P = 0.55	--
Bone metastases (yes vs no)	1.06 (0.74-1.53), P = 0.73	--
Brain metastases (yes vs no)	1.16 (0.64-2.11), P = 0.62	--
Lung metastases (yes vs no)	1.14 (0.74-1.75), P = 0.55	--
Liver metastases (yes vs no)	1.05 (0.72-1.53), P = 0.81	--
Lymph node metastases (yes vs no)	1.01 (0.70-1.46), P = 0.96	--
Hb baseline (<12 vs ≥12 mg/dL)	1.67 (1.05-2.67), P = 0.03	--
Neutrophils (≥8000 vs <8000)	2.62 (1.73-3.99), P < 0.0001	--
Lymphocytes (≤1000 vs >1000)	1.30 (0.87-1.94), P = 0.20	--
Platelets (≥400000 vs <400000)	2.48 (1.67-3.70), P < 0.0001	--
SII (≥1375 vs <1375)	3.35 (2.38-4.73), P < 0.0001	2.99 (2.07-4.31), P < 0.0001
NLR (≥3 vs < 3)	2.23 (1.52-3.28), P < 0.0001	--
PLR (≥232 vs <232)	2.37 (1.69-3.35), P < 0.0001	--
BMI (<25 vs ≥25)	1.50 (1.05-2.15), P = 0.02	1.58 (1.09-2.28), P = 0.01

Abbreviations: SII, systemic immune-inflammation index; PFS, progression-free survival; pts, patients; OS, overall survival; HR, hazard ratio; CI, confidence interval; ECOG, Eastern Cooperative Oncology Group; PS, performance status; IMDC, International mRCC Database Consortium; Hb, hemoglobin; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); SII systemic inflammatory index; NLR, neutrophil-lymphocyte ratio; PLR, platelets-lymphocyte ratio.

Table 4. Change in immune-inflammation index and clinical outcome

SII groups*		Median PFS (95% CI)	HR (95% CI)	P	1-year OS	HR (95% CI)	P
Low-Low	138	7.7 (6.2-9.2)			86%	1	
Low-High	49	5.7 (4.0-7.4)	1.32 (0.91-1.94)	0.14	48%	3.4 (2.1-5.8)	<0.0001
High-Low	28	4.6 (2.5-6.7)	1.43 (0.89-2.29)	0.14	53%	3.2 (1.7-5.9)	<0.0001
High-High	43	3.0 (2.6-3.4)	2.36 (1.61-3.44)	<0.0001	34%	6.1 (3.6-10.2)	<0.0001

*Four groups of SII changes: 1) low-low (baseline SII <1375 and follow-up SII <1375); low-high (baseline SII <1375 and follow-up SII ≥1375); high-low (baseline SII ≥1375 and follow-up SII <1375); and high-high (baseline SII ≥1375 follow-up SII ≥1375).

Abbreviations: SII, systemic immune-inflammation index; PFS, progression-free survival; pts, patients; OS, overall survival; HR, hazard ratio; CI, confidence interval.

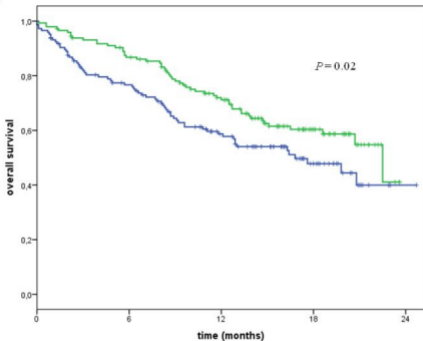
Note: For this analysis, patients with early disease progression/death or patients lost to follow-up before the landmark time were excluded.

Figure legends

Figure 1. Kaplan–Meier estimate of overall survival (OS) of patient according to BMI (Fig 1A), SII (Fig. 1B) and age (Fig 1C).

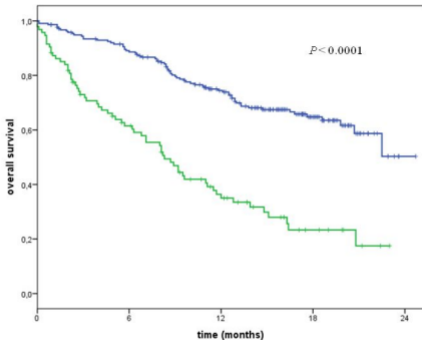
Figure 2. Kaplan–Meier estimate of overall survival (OS) according to the four groups identified using SII and BMI at baseline.

Figure 1 - A



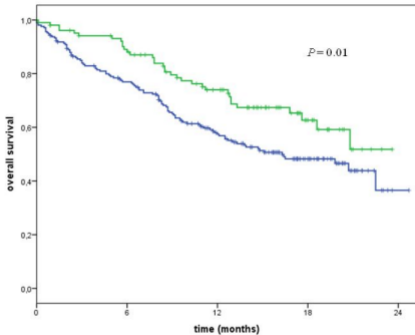
Green line BMI ≥25 146
Blue line BMI <25 147

Figure 1 - B



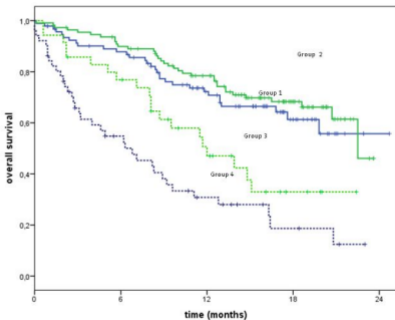
Green line	SII ≥ 1375	90
Blue line	SII < 1375	216

Figure 1 - C



Green line Age ≥ 70 105
Blue line Age < 70 208

Figure 2



Group 1 - SII < 1375 & BMI < 25 94
 Group 2 - SII < 1375 & BMI ≥ 25 111
 Group 3 - SII ≥ 1375 & BMI ≥ 25 35
 Group 4 - SII ≥ 1375 & BMI < 25 51

78
 97
 34
 23

51
 77
 11
 11

20
 36
 10
 4

1 - Blue line
 0 - Green line
 0 - Green dotted line
 0 - Blue dotted line

Clinical Cancer Research

Association of Systemic Inflammation Index and Body Mass Index With Survival in Patients With Renal Cell Cancer Treated With Nivolumab

Ugo De Giorgi, Giuseppe Procopio, Diana Giannarelli, et al.

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