

Clinicopathological significance of galectin-1 expression and percentage of galectin-1-expressing T cells in clear cell renal cell carcinoma

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Abstract

Introduction: This study investigates clinical significance of galectin-1 expression in carcinoma tissues, plasma, and lymphocytes of patients with clear-cell renal cell carcinoma (RCC).

Methods: Galectin-1 expression was investigated, using immunohistochemistry, in 91 clear-cell RCC tissue sections, five angioleiopomas tissue sections, and three oncocytomas tissue sections. As controls, normal tissue sections adjacent to each tumour and six benign renal tumour sections were examined. Plasma galectin-1 levels as measured by ELISA were compared in 39 patients. Proportions of galectin-1 expressing CD4⁺ and galectin-1 expressing CD8⁺ T lymphocytes in peripheral blood of these patients were detected by flow cytometry.

Results: The positive expression rate of galectin-1 in 91 clear-cell RCC tissues sections by immunohistochemistry was 87 (95.6%), with weak expression rate of 35.2 (32/91), moderate expression rate of 51.6% (47/91), and strong expression rate of 13.2% (12/91), respectively; whereas, 25% (2/8) renal benign tumour sections showed

weak galectin-1 expression, non-tumour tissue sections adjacent to carcinomas and another six (75%) renal benign tumour sections had negative galectin-1 expression. Plasma galectin-1 levels between patients with clear-cell RCC and with benign tumours were not significantly different ($p>0.05$). In patients with clear-cell RCC, we found a significantly higher proportion of galectin-1-expressing CD4⁺ lymphocytes ($p<0.05$) and galectin-1-expressing CD8⁺ lymphocytes ($p<0.05$) than in patients with benign tumours. Moreover, the level of galectin-1 expression was positively associated with stage and Fuhrman grade of clear-cell RCC.

Conclusions: Our results suggest that high level of galectin-1 expression in clear-cell RCC tissues may be a useful marker for clear-cell RCC. Our findings also reveal a new clinical significance of galectin-1 — that high proportions of galectin-1-expressing CD4⁺ and CD8⁺ lymphocytes were positively associated with poor clinicopathological features.

Introduction

Renal cell carcinoma (RCC) accounts for approximately 3% of adult malignancies.¹ The incidence of RCC increased over the last two decades in all regions of the world and ethnic groups. Although RCC develops insidiously, over 200,000 new cases of kidney cancer are diagnosed worldwide each year.² This improved detection is attributed to medical evaluation for unrelated conditions, routine health checkups and improved methods of detection, such as computed tomography or MRI. Despite increased detection of RCC, its prognosis varies widely; about 30% of patients have metastatic disease when diagnosed RCC, and approximately 30% of patients present with local or distant recurrence after radical or partial nephrectomy.^{3,4} Apart from RCC being highly resistant to chemotherapy, radiation and immunotherapy, there are also few predictive or prognostic markers identified. The identification of a prognostic marker for RCC would hasten the development new therapeutic strategies and improve survival of patients with RCC.

The galectins are a family of 15 mammalian galactoside-binding proteins that share a consensus amino acid sequence in their carbohydrate recognition domains (CRDs).⁵ Galectin-1 is first described member of galectins family, which is a 14 KDa protein consisting 135 amino acid.⁶ Galectin-1 is expressed in some malignant tumours. Galectin-1 is involved several biological activities, including cell adhesion, cell migration, cell apoptosis, cell proliferation, regulation of immunity, and tumour angiogenesis.⁷

RCC is classified as an immunogenic cancer, because it shows spontaneous regression and occasionally responds to immunotherapy. However, for unknown

reasons, the overall response rate of RCC to therapeutics remains low. And thus, it is common for RCC to evade immune surveillance. A previous study indicated that galectin-1 modulates T cell immune responses by virtue of a pro-apoptotic effect on Th subsets, induction of IL-10 synthesis, and Th2 cytokines skewing. Moreover, galectin-1 promotes the formation of immune-privileged sites.⁸

Little is known about role of galectin-1 in RCC. Therefore, in this study, we investigated galectin-1 expression in RCC, and in non-RCC Tissue sections. Concurrently, we assessed galectin-1 expression on peripheral blood T lymphocytes.

Methods

Patient characteristics

Ninety-nine patients with a renal tumor were enrolled in our study at the Department of Urology, Harbin Medical University Cancer Hospital from 2013 to 2015. Of these patients, 99 underwent nephrectomy or partial nephrectomy. Informed consent was obtained from all patients before inclusion in this study. The study was conducted in accordance with the Declaration of Helsinki. Kidney cancer was staged according to the TNM staging classification of the International Union against Cancer. All of the patients were confirmed to be free of any malignancies other than renal tumor. None of the patients had received any type of therapy before being admitted to the hospital, such as neoadjuvant chemotherapy, interferon or/ and interleukin 2 (IL-2), or target therapy. The mean age of the patients was 53 years (range 36 to 67 years). Of the 99 patients, 91 patients were confirmed as clear cell RCC and by post-operative pathological examinations, which included 63 male patients and 28 female patients, other 8 patients were diagnosed as renal benign tumor that consisted of 5 angioliolipomas and 3 oncocytomas. The patients were staged as follows: 48 in stage T1, 29 in stage T2, 11 in stage T3 and 3 in stage T4. The Fuhrman grade distribution was as follows: 43 were grade 1, 29 were grade 2, 16 were grade 3 and 3 were grade 4. There were no statistically significant differences in age and body mass index (BMI) among participants.

Blood samples preparing

Blood samples (10 ml) were obtained from the antecubital vein into heparinized tube of 93 patients on the first day after hospital admission. For control samples, we obtained 10 blood samples from health donors. Thereafter, plasma was prepared by means of centrifugation of peripheral blood at 3000 g for 25 min and stored at -80 °C until use. Peripheral blood mononuclear cells (PBMC) were isolated from heparinized venous blood samples by the standard Ficoll-Hypaque (Shanghai Reagent Secondary

Factory, Shanghai, China) density-gradient centrifugation method and were used immediately for flow cytometry analysis.

Flow cytometry analysis

The isolated mononuclear cells were washed twice using phosphate-buffered saline (PBS). Non-specific binding sites were blocked by incubation with mouse serum for 10 min at room temperature. Cells were stained with mononuclear antibody PE-labeled anti-human CD4 and mononuclear antibody (APC)-labeled anti-human CD8 (BD Pharmingen, San Diego, CA) for 15 min in dark at room temperature and then washed twice with PBS. Cells were centrifuged and the supernatant was removed. Cells were incubated in 1000 μ l 1 \times Permeabilizing Solution (eBioscience, San Diego, CA) for 10 min at room temperature in the dark. Thereafter, cells were washed twice with PBS, and were treated with rabbit anti- human Galectin-1 (LGALS1) antibody (Eptomics, Burlingame, CA) for 30 min at room temperature in dark. Following washing off unbound antibodies, the cells were stained with FITC-labeled anti-rabbit IgG (H+L) Antibody (KPL, Gaithersburg, MD) for 15 min at room temperature in the dark. After washing twice with PBS, the cells were resuspended in 4% paraformaldehyde in PBS. Flow cytometry analysis was performed on BD FACSCanto II (BD Accuri Cytometers, MI) and data was processed using CellQuest Pro software (BD Biosciences).

Immunohistochemistry

All tissue samples were collected immediately after surgery. All sample tissues included the primary tumor and the adjacent normal appearing tissue up to 0.5-2 cm from the margin of tumor site.⁹ Immunohistochemical studies were performed on formalin-fixed, paraffin-embedded, 4 μ m-thick tissue sections. Tissue sections were deparaffinized three times in xylene for a total of 15 min and subsequently rehydrated. To block endogenous peroxidase activity, the sections were incubated with 3% hydrogen peroxidase for 10 min. The rabbit anti- human Galectin-1 (LGALS1) antibody incubation was carried out for 2 h at 37 °C at an antibody dilution of 1:300. The sections were washed triple with PBS. Next, the sections were incubated for 30 min at room temperature with a biotinylated goat anti-rabbit IgG antibody (1:200; Vector Laboratories Inc., Burlingame, CA, USA). And finally, samples were incubated with peroxidase-conjugated streptavidin (Zhongshan gold bridge, Beijing, China). Color was developed by incubating the slides for 5 min with diaminobenzidine and nuclei were counterstained with hematoxylin. For negative controls, the primary antibodies were replaced with PBS. Positive controls were

provided by the kit supplier. The results were assessed by two independent pathologists who had no knowledge of the patient clinical status.

Quantitative reverse transcription-polymerase chain reaction

Total RNA was extracted from RCC tissues and adjacent kidney tissues using Trizol reagent (Invitrogen, Beijing China). Quantitative reverse transcription-polymerase chain reaction (qRT-PCR) was performed using a SYBR Premix Ex Taq™ Reverse Transcription-PCR kit (TaKaRa, Shiga, Japan). The primers for human Galectin-1 were 5'-GAGGTGGCTCCTGACGCTAA-3' (Forward) and 5'-CCTTGCTGTTGCACACGATG-3' (Reverse). The primers for β -actin were 5'-AGAAAATCTGGCACCACACC-3' (Forward) and 5'-TAGCACAGCCTGGATAGCAA-3' (Reverse). To synthesize first-strand cDNA from total RNA, each mixture reaction was incubated at 41 °C for 30 min. Thereafter, qPCR was performed at 95°C for 30 sec pre-denaturation, followed by 40 cycles of 95°C for 5 s, 60°C for 34 s. ratio of Galectin-1 to β -actin expression was calculated. All samples were run in triplicate.

Western blotting analysis

Western blotting was performed according to the previously described.¹⁸ Briefly, the tissues were lysed in SDS buffer and 100 μ g proteins was separated on 10% gradient SDS-polyacrylamide gels, transferred to PVDF, and incubated with rabbit anti-Galectin-1 antibody (1:500) overnight at 4°C. After incubation with peroxidase-conjugated rabbit anti-mouse IgG antibody (Cell Signaling Technologies, Beverly, MA, USA), β -actin was used as the loading control. After incubation with enhanced chemoluminescence reagent (Amersham Pharmacia Biotech, Piscataway, NJ, USA), protein expression was visualised after exposure to X-ray film.

ELISA

Patient plasma galectin-1 levels in were determined with a specific enzyme-linked immunosorbent assay (ELISA) kit (R&D Systems, Minneapolis, MN, USA), as previously described ELISA protocol.¹⁰ A 96-well plate was coated overnight at 4°C with mouse monoclonal anti-galectin-1 antibody and locked with 1% bovine serum albumin/PBS for 1 hour at room temperature before applying plasma for 1 hour at room temperature. Subsequently, wells were incubated with rabbit polyclonal anti-galectin-1 antibody for one hour followed by 30-minute incubation with biotinconjugated goat anti-rabbit IgG antibody (1: 400). Finally, horseradish peroxidase (HRP)-conjugated streptavidin was applied for 30 minutes and staining reaction was initiated by adding TMB staining solution. Reaction was stopped by

adding 1 volume of 1 mol/L H₂SO₄, and absorbance was measured at 450 nm. During all incubation steps, the wells were washed.

Statistical analysis

Plasma galectin-1 concentrations and percent of galectin-1 positive CD4⁺T cells or galectin-1 positive CD8⁺ T cells were compared between the RCC group and the renal benign tumor group. Statistical analysis was performed using SSPS software (version 19.0; Inc, IBM). The significance of differences was tested by various non-parametric methods such as the Mann-Whitney test. Spearman correlation test was used to evaluate the correlation between tumor nuclear grade and T cells expressed galectin-1. P < 0.05 was considered to be significant.

Results

Expression of galectin-1 in RCC tissues and adjacent non-carcinoma tissues.

Using immunohistochemistry, we examined galectin-1 expression in 91 clear cell RCC tissue sections. As controls, normal tissue sections adjacent to each tumor and eight benign renal tumor sections were examined. The benign renal tumors included 3 oncocytomas and 5 angioliolipoma. We analyzed the amount of galectin-1 expression in different tissues and found that galectin-1 expression was positive in 87/91 (95.6%) of clear cell RCC samples. Of all of RCC samples, weak, moderate and strong intensity of galectin-1 expression was seen in 32 (35.2%), 47 (51.6 %) and 12 sections (13.2%), respectively. In contrast, there was negative or weak expression of galectin-1 in both peritumoral normal tissue sections or in renal benign tumor sections, only 2/8 (25%) renal benign tumors showed a weak expression of galectin-1. The results are shown in Figure 1 A (a-f). Furthermore, we evaluated galectin-1 expression at protein and molecule levels in RCC, non-RCC and oncocytoma, respectively. Expression levels of galectin-1 protein and mRNA in RCC were significantly higher when compared to the surrounding normal kidney and oncocytoma tissues (Figure 1B,C and D).

Intracellular galectin-1 expression of peripheral blood lymphocytes in patients with RCC and with non-RCC

Using flow cytometry, intracellular galectin-1 expression was measured in freshly isolated peripheral blood lymphocytes from 91 patients with RCC and 8 patients with non-RCC. As shown in Figure 2A and 2B, our results revealed that a higher proportion of galectin-1-expressing CD4⁺ helper and CD8⁺ cytotoxic T cells were present in patients with RCC compared to patients with non-RCC, such as

oncocytoma and angioliolipoma ($p < 0.05$), however, there was no difference in the number of galectin-1-expressing CD4⁺ or CD8⁺ T cells between patients with RCC ($p > 0.05$). Representative examples are displayed in Figure 3A and B, and an isotype control is present in Figure 3C.

Relationship between fuhrman grade and peripheral blood T cells expressed galectin-1

According to the Spearman correlation test, a significant positive correlation was seen between the percentage of galectin-1⁺ CD4⁺ T cells ($p < 0.01$) or the percentage of galectin-1⁺ CD8⁺ T cells ($p < 0.01$) and the fuhrman grade. Similarly, no matter what percentage of galectin-1⁺CD4⁺ T cells or percentage of galectin-1⁺CD8⁺ T cell, was positively correlated with tumor stage (all $p < 0.01$), however, there was not correlated with tumor side, age and BMI (all $p > 0.05$). Our results indicate that percentage of galectin-1⁺ T cells may be a valuable predictive factor in clear cell RCC. The correlations between galectin-1 expression and clinicopathological features are shown in Table 1.

Circulating galectin-1 levels in patients with RCC or with non-RCC

Plasma galectin-1 levels ranged from 13.61 to 36.01 ng/ml (mean 23.62 ng/ml) and 22.62 to 29.09 ng/ml (mean 25.69 ng/ml) in patients with RCC and with non-RCC prior to surgery for removal of tumors. As shown in Figure 4, the results showed no statistically significant difference among the patient groups ($p = 0.436$). In addition, clinical features of patients with RCC (i.e. tumor size and TNM-classified stages) were not related to the circulating levels of galectin-1.

Discussion

In this study, we investigated the relationship between galectin-1 and RCC. We demonstrated for the first time that high galectin-1 expression in tumor sections of patients with RCC, whereas, galectin-1 expression appeared negative or weak in the peritumoral normal tissues and benign kidney tumor sections. A recent report also indicated that expression of galectin-1 mRNA was significantly higher in RCC compared to the adjacent normal kidney tissue,¹⁰ which is in line with our results. Moreover, a large proportion of peripheral blood CD4⁺ and CD8⁺ T cells had high galectin-1 expression. In addition, galectin-1 expression intensity is positively related to TNM-classified stage and the nuclear fuhrman grade of RCC. However, our study also revealed that circulating galectin-1 levels were not significantly altered in patients with RCC as compared to patients with benign tumors.

Our results support the idea that galectin-1 expression in the carcinoma can reflect RCC aggressiveness, because moderate to strong galectin-1 expression was observed in the RCC tissue sections in this study. According to the findings of several previous studies, galectin-1 expression was increased in several types of cancer, such as lung, colon, breast, prostate, ovarian cancer, and head and neck cancer.¹¹⁻¹⁶ It suggests that galectin-1 correlates with the malignant behavior of many types of carcinoma. However, clinical significance concerning galectin-1 in RCC remains unclear. Our data provide the evidence that galectin-1 may be an important biomarker for RCC. Huang CS et al. suggest that galectin-1 promotes kidney cancer progression through upregulation of CXCR4 via NF- κ B, so they concluded that both factors may be a novel prognostic factor for RCC,¹⁷ however, another study showed that galectin-1 mediates aggressiveness of RCC through the HIF-1 α -mTOR signaling axis.¹⁸ We suppose that galectin-1 could affect progression and prognosis of RCC through multiple signaling pathways. Therefore, further studies are warranted to explore the relationship between galectin-1 expression and long-term survival of patients with RCC, and the possible regulation of progression by galectin-1 in RCC. One of the most important findings of this study is that a significantly higher proportion of circulating CD4⁺ and CD8⁺ T cells expressed galectin-1 in patients with RCC than in patients with benign tumors. It is well known that RCC is an immunogenic cancer and resistant to current chemotherapy and radiation therapy. Moreover, low response to immunotherapy also critically affects prognosis of patient with advanced and metastasis RCC. It is possible that many factors contribute to weaken the anti-RCC immune response. For example, our previous study indicated RCC can inhibit maturation of dendritic cells and increase regulatory T cells.¹⁹ Both CD4⁺ and CD8⁺ T cells are important for effective anti-tumor immunity. However, high galectin-1 expression may result in impairment or attenuation of immune function in CD4⁺ and CD8⁺ T cells. According to previous studies, galectin-1 can block T cell activation, suppress T cell proliferation and induce T cell death.²⁰⁻²³ Furthermore, galectin-1 binding to activated Th cells also might be able to promote Tr1 cell differentiation,²⁴⁻²⁶ those combined effects, taken together with our new findings, suggest that galectin-1 may play an important role in escaping immune surveillance and promoting the establishment of immune-privileged sites in RCC. Additionally, low rates of response to immunotherapy in RCC may correlate with galectin-1 expression. It may help to evaluate or predict efficacy of immunotherapy by measuring galectin-1 expression in RCC. The fact that we did not find a significant difference in circulating plasma galectin-1 levels between in patients with RCC and

patients with benign kidney tumors could be explained by the findings that galectin-1 expression was mainly located in cytoplasm or that only a small amount of galectin-1 was secreted from either RCC cells or T cells. However, this contradicts a recent research that showed plasma levels of galectin-1 were significantly higher in RCC patients than in healthy controls.²⁷ Differences in results between our study and the previous study could be due to patients enrolled in the study.

A major limitation of this study is the small sample size. The lack of long-term follow-up data on these patients is another limitation. It remains unclear how these galectin-1-expressing T cells are promoting to immune-evasion in clear cell RCC, which should be addressed in the future. It may be a key that galectin-1 will be used as a novel therapeutic target for RCC.

Conclusion

Our study suggested that expression levels of galectin-1 are significantly higher in RCC tissue sections than it is in adjacent normal tissue sections and in benign kidney tumors tissue sections. Moreover, galectin-1 expression is positively related with TNM-classified stage and fuhrman grade in RCC. More interestingly, we found that the majority of circulating CD4⁺ and CD8⁺ T cells showed intracellular galectin-1 expression in patients with RCC. In conclusion, galectin-1 may be an important marker in evaluating aggressive behavior in RCC it may be involved in mediating tumor-immune privilege, and it may be a new target of immunotherapy for RCC.

References

1. Chow WH, Devesa SS, Warren JL, Fraumeni JF Jr (1999) Rising incidence of renal cell cancer in the United States. *JAMA* 281(17): 1628-1631.
2. Adami HO, Hunter DJ, Trichopoulos D. Textbook of cancer epidemiology. New York: Oxford University Press, 2002.
3. Patel C, Ahmed A, Ellsworth P (2012) Renal cell carcinoma: a reappraisal. *Urol Nurs* 32(4): 182-190.
4. Saito K, Kihara K (2010) Role of C-reactive protein as a biomarker for renal cell carcinoma. *Expert Rev Anticancer Ther* 10(12):1979-1989.
5. Barondes SH, Cooper DN, Gitt MA, Leffler H (1994) Galectins Structure and function of a large family of animal lectins. *J Biol Chem* 269(33):20807-20810.
6. Yang RY, Rabinovich GA, Liu FT (2008) Galectins. structure, function and therapeutic potential. *Expert Rev Mol Med* 10:e17.
7. Kim HJ, Jeon HK, Cho YJ, Park YA, Choi JJ, Do IG, Song SY, Lee YY, Choi CH, Kim TJ, Bae DS, Lee JW, Kim BG (2012) High galectin-1 expression correlates with poor prognosis and is involved in epithelial ovarian cancer proliferation and invasion. *Eur J Cancer* 48(12):1914-1921.
8. Cedeno-Laurent F, Dimitroff CJ (2012) Galectin-1 research in T cell immunity: past, present and future. *Clin Immunol* 142(2):107-116.
9. von Klot CA, Kramer MW, Peters I, Hennenlotter J, Abbas M, Scherer R, Herrmann TR, Stenzl A, Kuczyk MA, Serth J, Merseburger AS (2014) Galectin-1 and Galectin-3 mRNA expression in renal cell carcinoma. *BMC Clin Pathol* 14:15
10. Kopcow HD, Rosetti F, Leung Y, Allan DS, Kutok JL, Strominger JL (2008) T cell apoptosis at the maternal-fetal interface in early human pregnancy, involvement of galectin-1, *Proc. Natl Acad. Sci. U. S. A* 105(47): 18472-18477.
11. Hsu YL, Wu CY, Hung JY, Lin YS, Huang MS, Kuo PL (2013) Galectin-1 promotes lung cancer tumor metastasis by potentiating integrin $\alpha 6\beta 4$ and Notch1/Jagged2 signaling pathway. *Carcinogenesis* 34(6):1370-1381.
12. Barrow H, Rhodes JM, Yu LG (2011) The role of galectins in colorectal cancer progression. *Int J Cancer* 129(1):1-8.
13. Dalotto-Moreno T, Croci DO, Cerliani JP, Martinez-Allo VC, Dergan-Dylon S, Méndez-Huergo SP, Stupirski JC, Mazal D, Osinaga E, Toscano MA, Sundblad V, Rabinovich GA, Salatino M (2013) Targeting galectin-1 overcomes breast cancer-associated immunosuppression and prevents metastatic disease. *Cancer*

Res 73(3):1107-1117.

14. Laderach DJ, Gentilini LD, Giribaldi L, Delgado VC, Nugnes L, Croci DO, Al Nakouzi N, Sacca P, Casas G, Mazza O, Shipp MA, Vazquez E, Chauchereau A, Kutok JL, Rodig SJ, Elola MT, Compagno D, Rabinovich GA (2013) A unique galectin signature in human prostate cancer progression suggests galectin-1 as a key target for treatment of advanced disease. *Cancer Res* 73(1):86-96.
15. Kim HJ, Jeon HK, Cho YJ, Park YA, Choi JJ, Do IG, Song SY, Lee YY, Choi CH, Kim TJ, Bae DS, Lee JW, Kim BG (2012) High galectin-1 expression correlates with poor prognosis and is involved in epithelial ovarian cancer proliferation and invasion. *Eur J Cancer* 48(12):1914-1921.
16. Valach J, Fík Z, Strnad H, Chovanec M, Plzák J, Cada Z, Szabo P, Sáčková J, Hroudová M, Urbanová M, Steffl M, Pačes J, Mazánek J, Vlček C, Betka J, Kaltner H, André S, Gabius HJ, Kodet R, Smetana K Jr, Gál P, Kolář M (2012) Smooth muscle actin-expressing stromal fibroblasts in head and neck squamous cell carcinoma: increased expression of galectin-1 and induction of poor prognosis factors. *Int J Cancer* 131(11): 2499-2508.
17. Huang CS, Tang SJ, Chung LY, Yu CP Yu CP, Ho JY, Cha TL, Hsieh CC, Wang HH, Sun GH, Sun KH (2014) Galectin-1 upregulates CXCR4 to promote tumor progression and poor outcome in kidney cancer. *J Am Soc Nephrol* 25(7):1486-1495.
18. White NM, Masui O, Newsted D, Scorilas A, Romaschin AD, Bjarnason GA, Siu KW, Yousef GM (2014) Galectin-1 has potential prognostic significance and is implicated in clear cell renal cell carcinoma progression through the HIF/mTOR signaling axis. *Br J Cancer* 110(5):1250-1259
19. Teng L, Chen Y, Ding D, Dai H, Liu G, Li C (2014) Immunosuppressive effect of renal cell carcinoma on phenotype and function of dendritic cells. *Int Urol Nephrol* 46(5):915-920.
20. Rubinstein N, Alvarez M, Zwirner NW, Toscano MA, Ilarregui JM, Bravo A, Mordoh J, Fainboim L, Podhajcer OL, Rabinovich GA (2004) Targeted inhibition of Galectin-1 gene expression in tumor cells results in heightened T cell-mediated rejection; A potential mechanism of tumor-immune privilege. *Cancer Cell* 5(3):241-251.
21. Stillman BN, Hsu DK, Pang M, Brewer CF, Johnson P, Liu FT, Baum LG (2006) Galectin-3 and Galectin-1 bind distinct cell surface glycoprotein receptors to induce T cell death. *J Immunol* 176(2): 778-789.
22. Cedeno-Laurent F, Opperman M, Barthel SR, Kuchroo VK, Dimitroff CJ (2012)

- Galectin-1 triggers an immunoregulatory signature in Th cells functionally defined by IL-10 expression. *J Immunol* 188(7):3127-3137.
23. Bi S, Earl LA, Jacobs L, Baum LG (2008) Structural features of galectin-9 and Galectin-1 that determine distinct T cell death pathways. *J Biol Chem* 283(18):12248-12258.
 24. van der Leij J, van den Berg A, Harms G, Eschbach H, Vos H, Zwijs P, van Weeghel R, Groen H, Poppema S, Visser L (2007) Strongly enhanced IL-10 production using stable galectin-1 homodimers. *Mol Immunol* 44(4): 506-513.
 25. Cedeno-Laurent F, Barthel SR, Opperman MJ, Lee DM, Clark RA, Dimitroff CJ (2010) Development of a nascent galectin-1 chimeric molecule for studying the role of leukocyte galectin-1 ligands and immune disease modulation. *J Immunol* 185(8):4659-4672.
 26. Cedeno-Laurent F, Opperman MJ, Barthel SR, Hays D, Schatton T, Zhan Q, He X, Matta KL, Frank MH, Supko JG, Murphy GF, Dimitroff CJ (2012) Metabolic inhibition of galectin-1-binding carbohydrates accentuates anti-tumor immunity. *J Invest Dermatol* 132(2):410-420.
 27. Kaneko N, Gotoh A, Okamura N, Matsuo E, Terao S, Watanabe M, Yamada Y, Hamami G, Nakamura T, Ikekita M, Okumura K, Nishimura O (2013) Potential tumor markers of renal cell carcinoma: α -enolase for postoperative follow up, and galectin-1 and galectin-3 for primary detection. *Int J Urol* 20(5): 530-535

Figures and Tables

Fig. 1. Immunohistochemical evaluation of galectin-1 expression in renal cell carcinoma (RCC) tissues and adjacent normal tissues. **(A)(a–c)** Representative H&E staining of samples of RCC tissue, the renal benign tumor (oncocytoma) tissue and the adjacent normal renal tissues (original magnification 400×); **(d)** immunohistochemical evaluation showing increased galectin-1 expression in RCC compared with **(e)** adjacent normal tissue and **(f)** renal oncocytoma tissue (original magnification 400×); **(B and C)** Western blot analysis showing increased expression of Galectin-1 protein in RCC; **(D)** real-time PCR showing increased Galectin-1 mRNA expression in RCC when compared to the adjacent normal tissue samples and benign renal tumor samples (* $p < 0.05$).

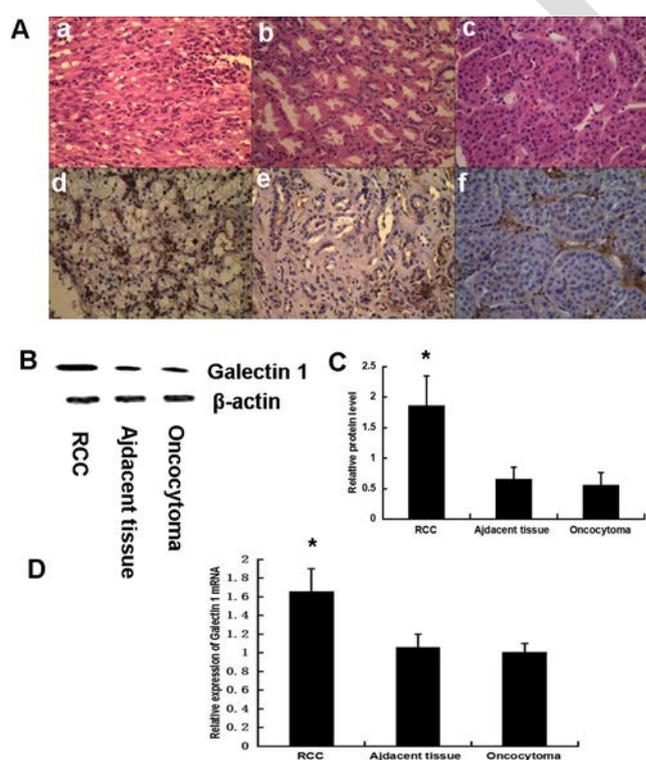


Fig. 2. Proportions of galectin-1-expressing CD4+ lymphocytes and galectin-1-expressing CD8+ lymphocytes in peripheral blood of patients with RCC and patients with non-renal cell carcinoma. **(A)** Proportions of galectin-1-expressing CD4+ lymphocytes; **(B)** proportions of galectin-1-expressing CD8+ lymphocytes.

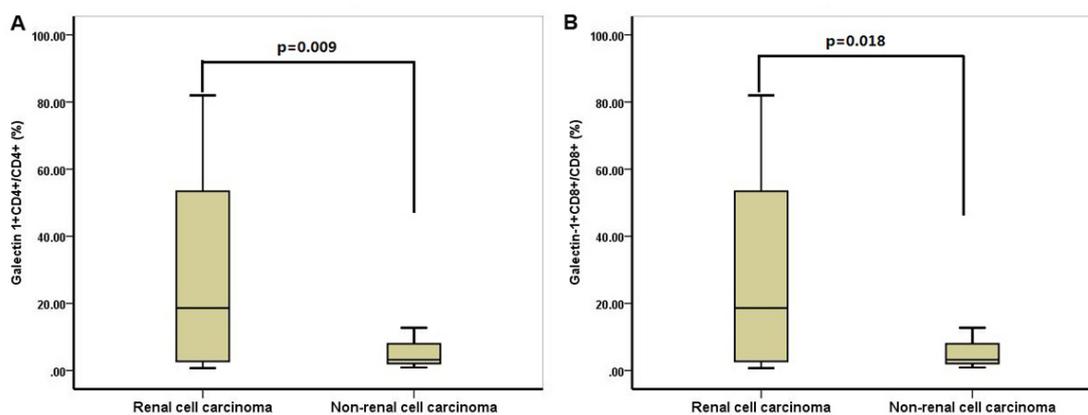
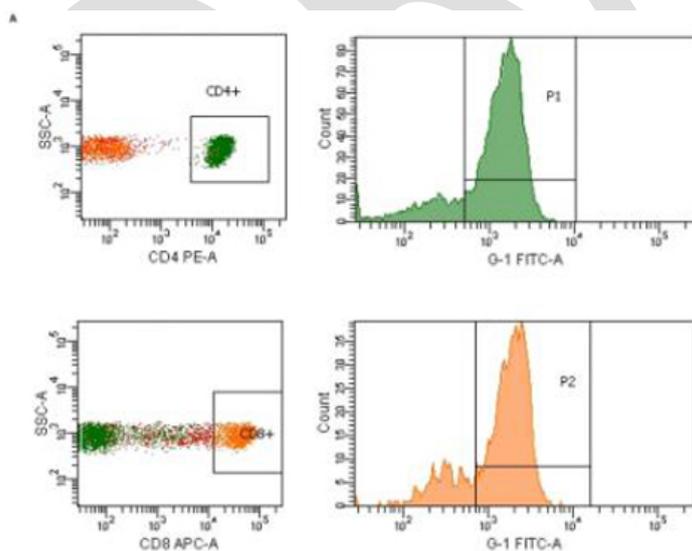


Fig. 3. Representative flow cytometric pattern showing intracellular galectin-1 expression of peripheral blood CD4+ and CD8+ lymphocytes in patients with renal cell carcinoma and oncocytoma. **(A)** RCC patient; **(B)** oncocytoma patient; **(C)** isotype control.



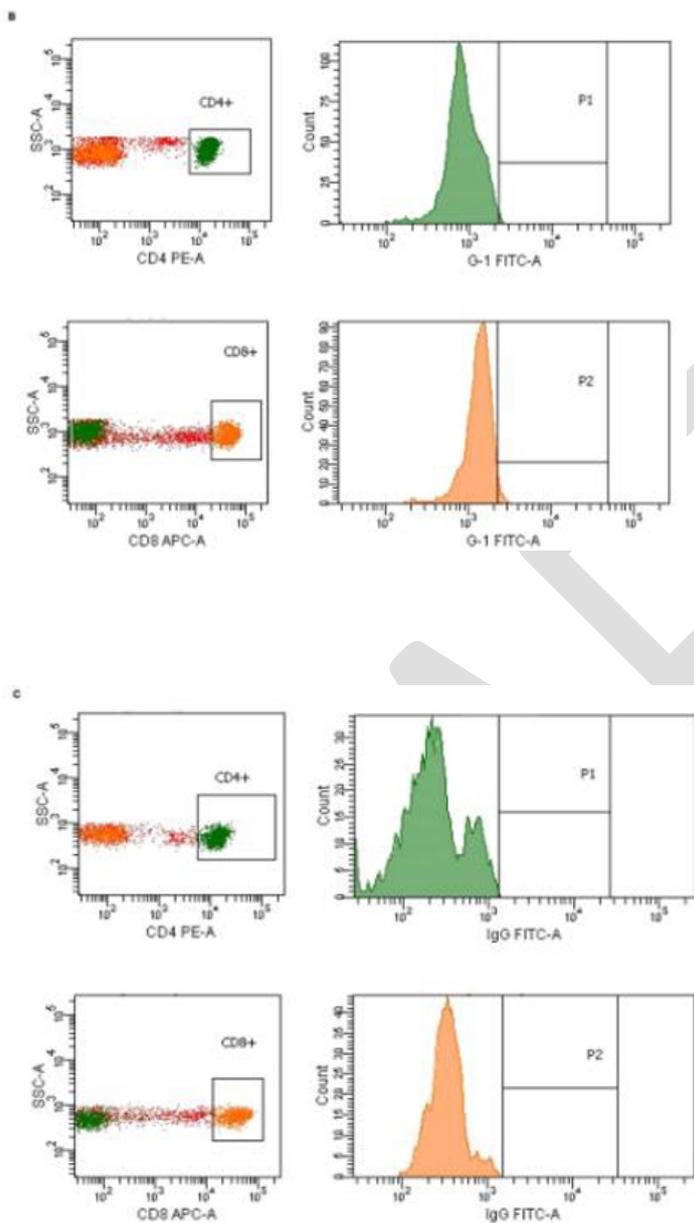


Fig. 4. Plasma concentrations of galectin-1 between patients with RCC and patients with non-renal cell carcinoma.

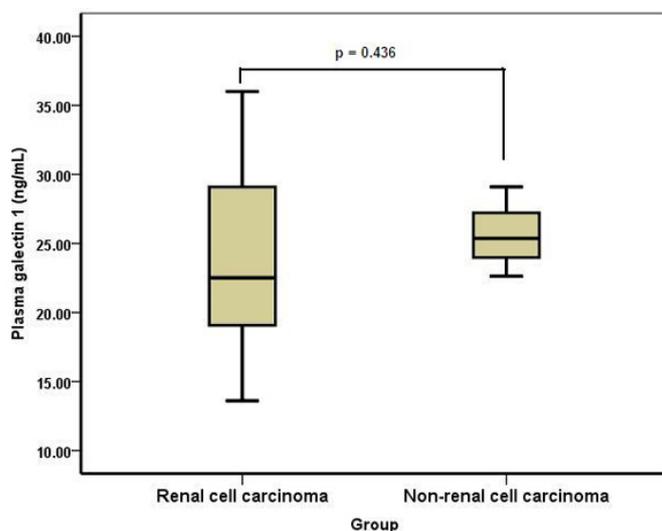


Table 1. Patients' characteristics

	Number	%
Gender		
Male	20	51.28
Female	19	48.72
Histology		
Clear-cell carcinoma	30	76.92
Chromophobic carcinoma	1	2.56
Mucinous tubular and spindle carcinoma	2	5.13
Renal benign tumor	6	15.38
Stage (T)		
T1a	22	66.67
T1b	9	27.27
T2a	1	3.03
T2b	1	3.03
T3	0	0.00
T4	0	0.00
Stage (N)		
N-	11	33.33
N+	0	0.00
Nx	22	66.67

Stage (M)		
M-	32	96.97%
M+	1	3.03%
Furhman grade		
1	18	54.55%
2	9	27.27%
3	6	18.18%
4	0	0%

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