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ORIGINAL ARTICLE

Impact of Urinary NGAL in Predicting Response of β2 Microglobulin after Bortezomib Base Chemotherapy in Multiple Myeloma Patients

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Abstract

Introduction: *Multiple myeloma is a common plasma cell malignancy where kidney damage can limit treatment options and lead to poor outcomes. Conventional markers for renal impairment have several limitations whereas NGAL is an early and robust marker of kidney injury and can reflect renal function more accurately than creatinine.*

Objective: *This study aims to explore the relationship between urinary NGAL and treatment response in patients with multiple myeloma with renal involvement.*

Materials and Method: *This prospective observational study was conducted in the Department of Nephrology, BSMMU, Dhaka. A total of 54 diagnosed Multiple myeloma patients were included according to the selection criteria. Baseline Urinary NGAL, Serum β2 microglobulin, S. creatinine levels were measured. Bortezomib based regimen was administered according to NHS guidelines. Follow up was given in the third month of treatment. Data were collected using a predefined data collection sheet. Statistical analyses were performed using software SPSS v-26*

Results: *The mean age of the participants was 55.7 years. 51.9% of patients were male and 48.1% were female. 77.8 % patients had eGFR value <60 ml/min and Serum â2 microglobulin was raised in 73.2 % patients. The optimal cut-off value for NGAL is 1.54 pg/mL, demonstrating high diagnostic accuracy with a sensitivity of 81.8%, specificity of 81.2%, positive predictive value of 72.0%, and a negative predictive value of 86.2%. Good response was found in 60% and 58.5% in respect to eGFR and S. β2 Microglobulin respectively. ROC analyses with β2 microglobulin, and eGFR also revealed similar findings.*

Conclusion: *This study demonstrates that urinary NGAL is a significant predictor of treatment response in multiple myeloma, particularly in advanced disease stages. Elevated urinary NGAL levels are more strongly linked to worsening renal function and disease burden than S. creatinine. With its high sensitivity and specificity, NGAL serves as a reliable biomarker for identifying patients at risk of renal impairment and monitoring treatment response.*

Keywords: *Serum β2 Microglobulin, Urinary NGAL and multiple myeloma.*

Introduction

Multiple Myeloma is one of the most common hematologic malignancies, particularly in the elderly patients, which represents a devastating disease that occurs due to uncontrolled proliferation of a plasma cell in bone marrow. Production of monoclonal paraproteins, immunoglobulins (MIg) or free light chains (FLCs), is a characteristic feature of myeloma that is the most important factor related to its clinical manifestations. Renal impairment (RI) is one of the most common complications of multiple myeloma

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(MM). The incidence of RI at diagnosis ranges from 20% to 50%[1]. RI is defined either as serum creatinine (sCr) above 2 mg/dL or as estimated glomerular filtration rate (eGFR) 60 mL/min/1.73 m2 or less (IMWG). Renal impairment is one of the four "CRAB" features (calcium level elevation, renal impairment, anemia, and bone lesions) that occur in Multiple Myeloma and cause myeloma-related organ dysfunction. There are several mechanisms by which Renal pathology occurs in multiple myeloma. Of them, cast nephropathy (CN) is dominant. CN can develop when light chain production is more than the capacity of the renal tubular cells to endocytose and to catabolize the free light chains that are filtered. As a result, excess free light chains can form aggregates and casts with uromodulin, which is a glycoprotein secreted by kidney tubules. These aggregates mostly form in the distal nephron, which leads to obstruction of the kidney tubules and concomitant inflammation.[2,3] Several conditions like Hypercalcemia, dehydration, use of nephrotoxic drugs like aminoglycoside antibiotics and/ or NSAIDs,and also use of contrast agents can contribute to the development of RI or can exacerbate existing RI through aggravating the toxic effect of light chains. Other renal pathologies that occur in patients with MM are Monoclonal immunoglobulin deposition disease (MIDD), amyloidosis, and rarely, kidney infiltration by neoplastic plasma cells or acquired adult Fanconi syndrome. Large molecular weight Ig (paraprotein) has limited capability to cross glomerular filtration barriers which leads to aggregation and deposition of Ig, that can induce local inflammation causing Glomerulopathies. Low molecular weight Ig (e.g., light chains) are Filtered across the glomerular filtration barrier and interact with tubular proteins and tubular cells that causes Cast nephropathy. Furthermore, the monoclonal light chain in Multiple Myeloma can stimulate the production of proinflammatory cytokines that are produced locally (interleukin-6, macrophage chemoattractant protein-1, and tumor necrosis factor α). All these can result in tubulointerstitial inflammation which progresses very rapidly to fibrosis. It has been shown that renal failure can be reversible for a substantial proportion of MM patients, while reversal may benefit long-term survival[4]. Severity of RI remains a deleterious organ complication with imparts an increased risk of early mortality and also a poor prognosis. So, the rapid diagnosis of RI in patients with MM and prompt institution of disease-specific treatment is very important for improving patient outcomes. The conventional assessment of renal function in patients with MM includes the measurement of sCr concentration, creatinine clearance (CrCl) and eGFR. Although sCr is dependent on individual and clinical characteristics of a person like age, gender, muscle mass, and drugs used. It also takes time to rise, upto 72 hours following injury. And it has a very large ''renal reserve" that means if GFR is not significantly reduced, sCr doesn't rise making it an insensitive and unreliable marker for the diagnosis of renal tubular injury. Cystatin C (Cys-C) also has been evaluated as a marker of kidney disease in patients with MM in a few studies, but the results have been inconsistent[5]. Dimopoulos et al.1 reported the data currently available regarding the application of KIM-1 in the setting of Multiple myeloma. He concluded that it has a very low utility because of varied pathogenesis of kidney dysfunction (as opposed to drug-induced nephrotoxicity). Therefore, there has been a lack of early biomarkers of structural kidney injury in myeloma patients. One of the most promising and earliest biomarkers of kidney injury is neutrophil gelatinase-associated lipocalin (NGAL) (lipocalin 2 [LCN2]). NGAL is a member of the lipocalin family which is a 25-kDa protein that is expressed at low levels in various human tissues, including the kidney. It is a small glycoprotein released by activated neutrophils and injured tubular cells. It is freely filtered through glomerular filtration barrier and is completely reabsorbed in the proximal tubules. There are several characteristic properties of NGAL: (1) it can be detected within a few hours (2-4 hrs), (2) it has a short half-life (ten minutes in serum), (3) fast renal elimination from circulation, and (4) it is very sensitive both in acute and chronic settings.2 NGAL dysregulation in cancer occurs through NGAL overexpression which results from both hypoxic and inflammatory stimuli (potentially via active nuclear factor kappa-light-chain-enhancer of activated B cells (NFK-B) and mitogen-activated protein kinase (MAPK) pathways) originating from the microenvironment of tumor. Interestingly, the activation of these pathways plays a very significant role in myeloma pathogenesis and also in related kidney lesions (induced by excess processing of FLC). In MM patients, the serum/plasma/urinary NGAL levels share a relationship with the levels of M protein, international staging system (ISS) stage, and disease status, indicating its utility as a bimodal marker of both tumor burden and renal injury. Du et al.6 showed positive correlation between urinary NGAL and beta 2 microglobulin, eGFR, and urinary free light chain ratio and concluded that NGAL can detect renal damage and also reflect tumor burden.

Effective anti- myeloma chemotherapeutic regimens with novel Chemotherapeutic agents as well as high cut off hemodialysis (HCO) can lead to renal recovery and improved survival in patients having more pronounced renal impairement. But there is lack of biomarkers that can predict renal outcomes in Multiple Myeloma. Dimopoulos et al.[7] studied MM patients with renal impairment. After giving Bortezomib based treatment renal response (Rrenal) has been achieved in 63% of patients including 45% with major renal response and 40 % became dialysis independent. Median time to renal response was one month after starting of the treatment. Lower levels of NGAL were associated with higher probability of major renal response among patients with renal impairment. Thus NGAL can be an independent predictor of major renal response in diagnosed MM patients with renal impairment. Thus, NGAL could identify renal involvement in MM patients very early and guide that who should be treated with more aggressive therapies and more effective and rapidly acting novel antimyeloma regimens.

Methods:

After getting Institutional Review Board approval, this prospective observational study was conducted on 54 patients (diagnosed case of Multiple Myeloma) at Hematology and Nephrology Department, BSMMU. After getting informed written consent total 67 patients were included (59 from Hematology department and 8 from Nephrology department. At first 97 patients who were diagnosed as Multiple Myeloma were screened, among them 67 patients had renal involvement [either raised S.creatinine or proteinuria (uPCR > 0.3g/day)]. Thirteen patients were dropped out (11 due to development of sepsis and 2 patients expired). The demographic information, relevant history, examination findings and investigation reports of all the study subjects has been recorded in the data collection sheet. Urine and blood sample has been collected before starting chemotherapy and after three months of giving Bortezomib based therapy according to NHS protocol.

β2MG measurement:

Concentrations of serum β2MG has been performed on VIDAS PC Immuno- Fluorescent Analyzer by using Enzyme Linked Fluorescent Assay (ELFA) technique. 10-20 ml blood was collected from each study subject. Sample was sent to the laboratory as early as possible (not > 2 hours). If not possible then it was preserved in refrigerator (+2ºC to +8ºC). After diluting the sample, the β2 microglobulin in the sample binded with the specific monoclonal antibody. The β2 microglobulin retained was revealed by an alkaline phosphatase- labeled polyclonal anti-human β2 microglobulin antibody (sheep). The conjugate enzyme catalyzed the hydrolysis of this substrate into a fluorescent product (4-Methylumbelliferone), the fluorescence of which was measured at 450 nm. The intensity of the fluorescence was proportional to the concentration of β2 microglobulin present in the sample. At the end of the assay, results were automatically calculated by the instrument in relation to the calibration curve stored in memory.

Data processing and statistical analysis:

Data analysis was done by SPSS Version 26. Continuous variables were compared using unpaired t-test and categorical variables were compared using Chi-square test. Pearson's correlation analysis was used to observe the correlation of urinary NGAL with Beta 2 microglobulin and eGFR. ROC curve analysis was done to determine sensitivity and specificity of urinary NGAL in predicting treatment response. A value of p <0.05 was considered as statistically significant at 95% confidence interval (CI).

Results

Table-I

Demographic characteristics of the study patients (n=54)

Variables	Frequency (n)	Percentage (%)
Age group (years)		
20-40	7	13.0
41-60	29	53.7
>60	18	33.3
Mean±SD	55.7±11.8	
Range (min-max)	25-78	
Sex		
Male	28	51.9
Female	26	48.1

Maximum patients were in age group 41-60 years followed by over 60 years (33.3%). The mean age of the participants was 55.7 years having a standard deviation of 11.8. The gender distribution was 51.9% of patients being male and 48.1% female.

Table-II

Distribution of study patients by BMI categories (n=52)

BMI (kg/m2)	Frequency	Percentage
Normal weight (18.5-24.99)	39	72.2
Overweight (25-29.9)	15	27.8
Total	54	100.0
Mean±SD	23.5 ± 1.79	
Range (min-max)	20.1 - 27.4	

Majority of participants (72.2%) fall into the normal weight category with a BMI ranging from

18.5 to 24.99 kg/m². Overweight individuals, defined by a BMI between 25 and 29.9 kg/m²,

constitute 27.8% of the sample. Mean BMI is 23.5 kg/m² with a standard deviation of 1.79.

Table-III

Distribution of the study patients by clinical presentation (n=54)

Clinical presentation	Frequency	Percentage
Hypertension	25	46.3
Anemia		
Mild (9-12 g/dl)	39	72.2
Moderate to severe (<9 g/dl)	12	22.2
Oedema		
+	18	33.3
++	3	5.6

Hypertension was prevalent in 46.3% of the study. Anemia was noted in various degrees, with

mild anemia affecting 72.2% of the patients, while 22.2% experience moderate to severe anemia. 33.3% of patients present with mild edema, and 5.6% have more pronounced edema (++).

Table-IV

Distribution of the study patients by baseline investigations (n=54)

Investigation	Frequency	Percentage
Urinary PCR (g/g)		
<3.5	49	91.7
>3.5	5	9.3
eGFR (ml/min)		
<60	42	77.8
>60	12	22.2
S. β2 Microglobulin (mg/L)		
<3.5	15	27.8
>3.5	39	73.2

Urinary protein-to-creatinine ratio (PCR) results show that 91.7% of patients have a ratio <3.5 g/g, with only 9.3% exceeding 3.5 g/g. The estimated glomerular filtration rate (eGFR) is below 60 ml/min in 77.8% of patients. S. β2 microglobulin level was >3.5 in 73.2% patients.

Table-V

Distribution of the study patients by investigations after treatment (n=54)

Investigations	Frequency	Percentage
Urinary PCR (g/g)		
<1.0 (good response)	32	59.3
>1.0 (not good response)	22	40.7
eGFR (ml/min)		
<60 not good response	32	59.3
>60 good response	22	40.7
S. â2 Microglobulin (mg/L)		
<3.5 good response	31	57.6
>3.5 not good response	23	42.4

Urinary protein-to-creatinine ratio (PCR) results show that 59.3% of patients have a good response. Also good response was found in 59% and 57% in respect to eGFR, S. β2 Microglobulin respectively.

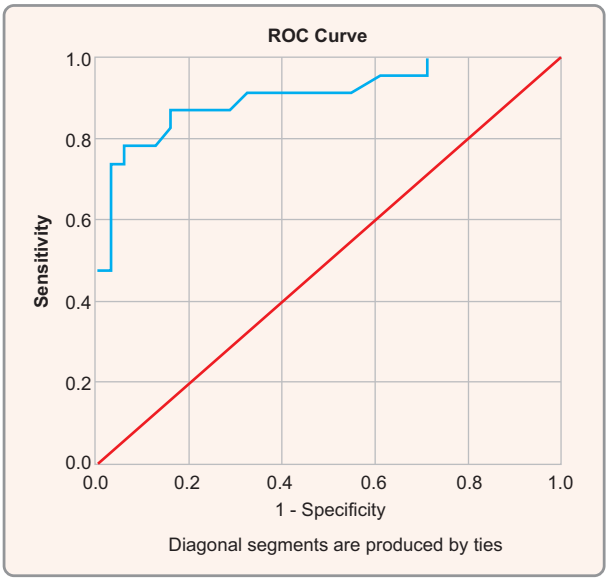

Figure 1: *ROC curve analysis performed to predict the best cut off value of NGAL (before treatment) related to β2 Macroglobulin >3.5 after treatment (not good response)*

Table-VI

ROC Analysis for before treatment NGAL with after treatment β2 Macroglobulin >3.5 (not good response) (n=54)

Parameters	Value
Area Under the Curve (AUC)	0.906
95% Confidence Interval (AUC)	0.820 –0.992
p-value	<0.001
Optimal Cut-off Value (pg/mL)	1.49
Sensitivity (%)	87.0%
Specificity (%)	83.9%
Positive Predictive Value (%)	80.0%
Negative Predictive Value (%)	89.7%
Accuracy (%)	85.2%

The ROC analysis of NGAL levels before treatment for predicting an unfavorable response (B2 Macroglobulin >3.5 after treatment) shows a high AUC of 0.906, indicating excellent discriminative power. The 95% confidence interval (0.820–0.992) confirms the precision of this estimate, with a statistically significant p-value of <0.001. The optimal NGAL cut-off value of 1.49 pg/mL demonstrates good sensitivity (87.0%) and specificity (83.9%), meaning it is effective at identifying patients likely to experience a poor response to treatment. The positive predictive value of 80.0% and negative predictive value of 89.7% indicate a strong predictive capacity, with an overall accuracy of 85.2%.

Table-VII

Yuden Index at different cut off value of urinary NGAL to predict B2

Macroglobulin >3.5 (not good response)

NGAL (ng/ml)	Sensitivity	1 - Specificity	Yuden Index
1.370	0.870	0.290	0.580
1.390	0.870	0.226	0.644
1.430	0.870	0.194	0.676
1.485	0.870	0.161	0.709
1.535	0.826	0.161	0.665
1.640	0.783	0.129	0.654
1.770	0.783	0.097	0.686

Best cut off value of NGAL is 1.485.

Discussion:

The demographic characteristics of the study group reveal a predominance of middle- aged to older adults, with the majority (53.7%) being between the ages of 41-60 years, followed by 33.3% aged over 60 years. This age distribution is consistent with the typical age profile of multiple myeloma patients, as the disease is more prevalent in older individuals[8]. The mean age of 55.7 years, having SD of 11.8, further aligns with the global epidemiological data that show multiple myeloma is more common in individuals over 50 years[9]. The relatively balanced gender distribution, with males representing 51.9% and females 48.1%, reflects a non- significant gender bias in multiple myeloma incidence, although some studies have suggested a slight male predominance in certain populations[10].

Body Mass Index (BMI) distribution, as seen in this study, reflects the role of patient weight status in predicting treatment responses for multiple myeloma. In this study, 72.2% of patients maintained a healthy BMI, while 27.8% were classified as overweight. These BMI trends align with research, suggesting a close relationship between body composition and treatment efficacy in cancer patients[11]. BMI influences not only response to chemotherapy but also metabolic complications, further stressing the importance of monitoring BMI in multiple myeloma[9].

The clinical features observed in this study, particularly hypertension in 46.3% of patients and varying levels of anemia and proteinuria, align with existing literature on multiple myeloma. Hypertension is frequently reported as a comorbidity in myeloma patients, potentially linked to kidney dysfunction or disease progression. Anemia, present in a significant number of patients, can be attributed to bone marrow infiltration by malignant plasma cells or renal impairment. Similar findings have been documented in recent studies, like, 12 which emphasize the importance of anemia and renal impairment in multiple myeloma. Edema and proteinuria, noted in this study, further indicate compromised renal function.

The data regarding investigations highlight key markers crucial for predicting treatment response in multiple myeloma, particularly focusing on renal function and disease progression. Urinary protein-to-creatinine ratio (PCR) results show that 91.7% of patients have a ratio <3.5 g/g, with only 9.3% exceeding 3.5 g/g. it shows that most of the patients presented with

subnephrotic proteinuria. The estimated glomerular filtration rate (eGFR) is below 60 ml/min in 77.8% of patients. This is consistent with findings in other studies where renal impairment is a common manifestation in multiple myeloma due to the toxic effects of monoclonal light chains

on the kidneys[9]. S. β2 microglobulin level was >3.5 in 73.2% patients and FLC ratio was raised (>1.65) in 71.4% of patients, which shows that most patients had higher tumor burden. Proteinuria, detected in all of the patients, is a known early indicator of kidney involvement in multiple myeloma, highlighting the role of urinary NGAL as a predictive biomarker for renal injury and disease progression[11]. These findings align with recent literatures, which support NGAL's potential in predicting both renal damage and treatment outcomes[13].

After giving treatment with Bortezomib based regimen urinary protein-to-creatinine ratio (PCR) results show that 59.3% of patients have a good response who had uPCR value below 1 g/g. Also good response was found in 59% in respect to eGFR (>60 ml/min), 57% in respect to S. β2 Microglobulin (<3.5 mg/L).

Urinary PCR values, which increased significantly with disease progression (p=0.033), indicate elevated proteinuria in advanced stages. Similarly, serum creatinine levels also rose (p=0.01), and eGFR decreased (p=0.022), highlighting worsening renal function with disease advancement. These results correlate with studies that demonstrate NGAL's role as a biomarker for early kidney damage, particularly in advanced multiple myeloma stages where renal impairment is prevalent[7,14]. Monitoring NGAL levels before and after treatment may help clinicians assess the extent of renal recovery or ongoing damage, providing valuable insights into a patient's response to therapy. These findings, which underscore the potential of NGAL to serve as a non-invasive marker that can complement existing diagnostic methods in monitoring renal health and treatment efficacy in multiple myeloma patients[15]. In summary, the strong correlation between NGAL, β2-microglobulin, and eGFR highlights its potential as a key biomarker for evaluating renal function and treatment response in multiple myeloma. Incorporating NGAL monitoring into clinical practice could improve patient outcomes by enabling timely adjustments to therapeutic strategies based on real-time assessment of kidney health.

The ROC analysis of NGAL levels before treatment for predicting an unfavorable response

(B2 Macroglobulin >3.5mg/L after treatment) shows a high AUC of 0.906, indicating excellent discriminative power. The 95% confidence interval (0.820–0.992) confirms the precision of this estimate, with a statistically significant p-value of <0.001. The optimal NGAL cut-off value of 1.49 pg/mL demonstrates good sensitivity (87.0%) and specificity (83.9%), meaning it is effective at identifying patients likely to experience a poor response to treatment. The positive predictive value of 80.0% and negative predictive value of 89.7% indicate a strong predictive capacity, with an overall accuracy of 85.2%. Baseline NGAL levels with after treatment β2 Macroglobulin level shows significant associations in biomarker levels. Baseline

NGAL <1.5 group had less response to treatment. Most patients (83.9%) achieving good response had baseline urinary NGAL <1.5. β2-microglobulin has long been associated with tumor load in multiple myeloma, and its elevation is indicative of poor prognosis and aggressive disease[16]. Similar studies have reported that NGAL correlates with renal impairment and disease progression, and it is increasingly being recognized as a valuable tool in the clinical management of patients with multiple myeloma[17]. Urinary NGAL, in conjunction with β2-microglobulin, provides a comprehensive picture of disease activity and renal function in multiple myeloma, and its role in predicting treatment response should be further explored in clinical practice.

The analysis of serum creatinine levels before treatment in multiple myeloma patients reveals that there is no strong association with post-treatment renal response, as indicated by the eGFR values. A substantial proportion of patients (19.2%) who had serum creatinine level below 1.4 mg/dl had no response and one patient went to ESRD requiring maintenance hemodialysis. Three patients who had S. creatinine levels below 3 mg/dl ultimately went on to develop ESRD and became dialysis dependent and their NGAL levels were higher. But there were other patients who had elevated S.creatinine more than 3 mg/dl but they did not develop ESRD neither they required dialysis as their baseline NGAL level were not that much elevated. Even two patients who required dialysis in the first month later became dialysis independent and his NGAL level was not very high. So this study reveals that S. creatinine levels cannot predict the treatment response in Multiple Myeloma like Urinary NGAL. Before treatment, patients with serum creatinine <1.4 mg/dl had significantly lower urinary protein-to-creatinine ratios (PCR), indicating less severe renal dysfunction compared to those with levels >1.4 mg/dl. This aligns with the idea that elevated serum creatinine often correlates with worsening kidney function and higher urinary protein excretion.18 Elevated β2-microglobulin, a marker of renal impairment and multiple myeloma disease activity, is strongly associated with

worse outcomes[19]. Urinary PCR provides additional insights into the severity of renal damage, with high PCR values indicating significant proteinuria and correlating with worse renal outcomes.

Urinary NGAL, a known marker of kidney injury, has increasingly been explored for its relevance in predicting responses to treatments, especially in conditions like multiple myeloma, where renal function plays a pivotal role. Recent studies suggest NGAL could serve as an effective non-invasive biomarker for acute kidney injury and its association with serum creatinine levels indicates potential utility in monitoring treatment responses. A study by Allegretti et al. demonstrates the efficacy of NGAL in distinguishing different types of kidney injuries and predicting mortality in a cohort with cirrhosis and acute kidney injury, showcasing its diagnostic potential in complex conditions.

In this context, NGAL appears to outperform traditional markers like serum creatinine, further supported by studies such as Allegretti et al., which emphasize NGAL's utility in distinguishing between different types of kidney injury[20]. Its accuracy in predicting poor renal outcomes is critical, especially when other biomarkers may fall short. Studies have shown that urinary NGAL is a promising biomarker for assessing renal function in multiple myeloma patients, particularly as it correlates with disease progression and kidney damage[21]. A lower NGAL level may indicate a better treatment response and less renal impairment, which aligns with existing research linking NGAL levels to kidney function outcomes. Research by Allegretti et al.20 demonstrated that NGAL serves as a reliable marker for both acute and chronic kidney injuries, reinforcing its predictive value in multiple myeloma settings[20]. This lack of disparity in renal markers across creatinine groups suggests that serum creatinine alone may not be asensitive indicator of renal function or treatment response. Instead, NGAL appears to provide a much nuanced and precise measurement of renal status in multiple myeloma patients[9]. As such, incorporating urinary NGAL as a routine assessment tool could enhance the early detection of renal complications and help to tailor various treatment strategies to improve outcomes of patients[11].

Conclusion

The findings from this study provide evidence that urinary NGAL is a significant predictor of treatment response in multiple myeloma. The elevated levels of NGAL, particularly in patients with advanced disease stages, are strongly correlated with worsening renal function and higher disease burden. These results indicate that NGAL can serve as a reliable biomarker for identifying patients at risk of renal impairment and for monitoring their treatment response. While serum β2-microglobulin, LDH, and other renal function indicators also reflect disease severity, NGAL's high sensitivity and specificity make it an effective tool in clinical settings. Thus, urinary NGAL can offer a significant predictive value for personalized treatment strategies in multiple myeloma.

References

1. Dimopoulos MA, Christoulas D, Kastritis E, Gkotzamanidou M, Margeli A, Kanellias N, Eleutherakis-Papaiakovou E, Papassotiriou I, Terpos E. Tubular Damage Is Ubiquitous in Newly-Diagnosed Patients with Multiple Myeloma: Comparison of Three Urinary and Two Serum Markers of Kidney Injury. Blood. 2012;120(21):2919.
2. Kastritis E, Anagnostopoulos A, Roussou M, Gika D, Matsouka C, Barmparousi D, Grapsa I, Psimenou E, Bamias A, Dimopoulos MA. Reversibility of renal failure in newly diagnosed multiple myeloma patients treated with high dose dexamethasone-containing regimens and the impact of novel agents. haematologica. 2007;92(4):546-9.
3. Hutchison CA, Bridoux F. Renal impairment in multiple myeloma: time is of the essence. Journal of Clinical Oncology. 2011;29(11):e312-3.
4. Knudsen LM, Hjorth M, Hippe E, Nordic Myeloma Study Group. Renal failure in multiple myeloma: reversibility and impact on the prognosis. European journal of haematology. 2000;65(3):175-81.
5. Nückel H, Langer C, Herget-Rosenthal S, Wichert M, Assert R, Döhner H, Dührsen U, Liebisch P. Prognostic significance of serum cystatin C in multiple myeloma. International journal of hematology. 2012;95:545-50.
6. Du W, Shen T, Li H, Liu Y, He L, Tan L, Hu M. Urinary NGAL for the diagnosis of the renal injury from multiple myeloma. Cancer Biomarkers. 2017 Jan 1;18(1):41-6.
7. Dimopoulos MA, Roussou M, Kastritis E, Margeli A, Eleutherakis-Papaiakovou E, Ntanasis-Stathopoulos I, Kanellias N, Papassotiriou GP, Fotiou D, Migkou M, Gavriatopoulou M. Serum Neutrophil Gelatinase-Associated Lipocalin Independently Predicts for Renal Response in Myeloma Patients with Severe Renal Impairment. Blood. 2019;134:1877.
8. Lesokhin AM, Tomasson MH, Arnulf B, Bahlis NJ, Miles Prince H, Niesvizky R, Rodrßguez-Otero P, Martinez-Lopez J, Koehne G, Touzeau C, Jethava Y. Elranatamab in relapsed or refractory multiple myeloma: phase 2 MagnetisMM-3 trial results. Nature medicine. 2023;29(9):2259-67.

9. Rodriguez-Otero P, Ailawadhi S, Arnulf B, Patel K, Cavo M, Nooka AK, Manier S, Callander N, Costa LJ, Vij R, Bahlis NJ. Ide-cel or standard regimens in relapsed and refractory multiple myeloma. New England Journal of Medicine. 2023;388(11):1002-14.

10. San-Miguel J, Dhakal B, Yong K, Spencer A, Anguille S, Mateos MV, Fernández de Larrea C, Martínez-López J, Moreau P, Touzeau C, Leleu X. Cilta-cel or standard care in lenalidomide-refractory multiple myeloma. New England Journal of Medicine. 2023 Jul 27;389(4):335-47.

11. Hansen DK, Sidana S, Peres LC, Colin Leitzinger C, Shune L, Shrewsbury A, Gonzalez R, Sborov DW, Wagner C, Dima D, Hashmi H. Idecabtagene vicleucel for relapsed/refractory multiple myeloma: real-world experience from the myeloma CAR T consortium. Journal of Clinical Oncology. 2023 Apr 10;41(11):2087-97.

12. Ludwig, H. et al. Multiple Myeloma: Clinical Presentation and Impact on Survival, Journal of Clinical Oncology, 2021;39(5):456-462.

13. Gavrilovici C, Dusa CP, Iliescu Halitchi C, Lupu VV, Spoiala EL, Bogos RA, Mocanu A, Gafencu M, Lupu A, Stoica C, Starcea IM. The role of urinary NGAL in the management of primary vesicoureteral reflux in children. International Journal of Molecular Sciences. 2023;24(9):7904.

14. Romejko K, Markowska M, Niemczyk S. The review of current knowledge on neutrophil gelatinase-associated lipocalin (NGAL). International journal of molecular sciences. 2023;24(13):10470.

15. Marakala, V., 2022. Neutrophil gelatinase-associated lipocalin (NGAL) in kidney injury–A systematic review. *Clinica chimica acta*, *536*, pp.135-141.

16. Li D, Zhang Q, Li L, Chen K, Yang J, Dixit D, Gimple RC, Ci S, Lu C, Hu L, Gao J. â2- microglobulin maintains glioblastoma stem cells and induces M2-like polarization of tumor-associated macrophages. Cancer Research. 2022;82(18):3321-34.

17. Sun Q, Kang Z, Li Z, Xun M. Urinary NGAL, IGFBP-7, and TIMP-2: novel biomarkers to predict contrast medium-induced acute kidney injury in children. Renal Failure. 2022;44(1):1202-7.

18. Nakada T, Kudo T, Ito K. Quantitative consideration of clinical increases in serum creatinine caused by renal transporter inhibition. Drug Metabolism and Disposition. 2023;51(9):1114-26.

19. Vega-Vega O, Caballero-Islas AE, Toro-Cisneros D, Hernandez-Ordoñez SÓ, Arvizu- Hernández M, Martínez-Rueda A, Camacho-Colin D, Gómez-Correa LL, Correa-Rotter R. Improved â2-microglobulin and phosphorous removal with expanded hemodialysis and online hemodiafiltration versus high-flux hemodialysis: a cross-over randomized clinical trial. Blood Purification. 2023;52(7-8):712-20.

20. Allegretti AS, Parada XV, Endres P, Zhao S, Krinsky S, Hillien SA, Kalim S, Nigwekar SU, Flood JG, Nixon A, Simonetto DA. Urinary NGAL as a diagnostic and prognostic marker for acute kidney injury in cirrhosis: a prospective study. Clinical and translational gastroenterology. 2021;12(5):e00359.

21. Mailankody S, Matous JV, Chhabra S, Liedtke M, Sidana S, Oluwole OO, Malik S, Nath R, Anwer F, Cruz JC, Htut M. Allogeneic BCMA-targeting CAR T cells in relapsed/refractory multiple myeloma: phase 1 UNIVERSAL trial interim results. Nature medicine. 2023;29(2):422-9.