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ORIGINAL RESEARCH

# Evaluation of Serum Levels of Kidney Injury Molecule-1 (KIM-1) and Neutrophil Gelatinase-Associated Lipocalin (NGAL) as Potential Biomarkers of Renal Tubular Damage in Brucellosis Patients

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**Background:** Brucellosis is a zoonotic and multisystemic disease that is widespread worldwide and can present with many different clinical conditions, ranging from asymptomatic to serious and fatal conditions. Brucellosis may be linked to renal tubular and acute kidney damage, nephrotic syndrome, and various types of nephropathies.

**Objective:** Our research was carried out prospectively to investigate the relationship between brucellosis and various biochemical markers and particularly to investigate the role of renal tubular damage biomarkers.

**Methods:** Demographic and biochemical data from 60 controls and 60 brucellosis patients were included in the study. Kidney injury molecule-1 (KIM-1) and Neutrophil gelatinase-associated lipocalin (NGAL) were analyzed by. The diagnostic accuracy of KIM-1 and NGAL for brucellosis was assessed using receiver operating characteristic (ROC) curve analysis.

**Results:** According to our findings, significant differences of KIM-1 and NGAL were observed between brucellosis and healthy patients. A high AUC (area under the curve) value of 0.742 (95% CI: 0.616–0.868) and 0.835 (95% CI: 0.729–0.941) was observed for KIM-1 and NGAL, respectively.

**Conclusion:** Serum levels of KIM-1 and NGAL, which are renal tubular damage markers, where higher in Brucellosis than in healthy patients. These biomarkers can contribute to the rapid and accurate diagnosis of brucellosis regarding the involvement of nephropathies and to the standardization of comprehensive diagnostic warning indicators.

**Keywords:** brucellosis, diagnosis, renal tubular damage, KIM-1, NGAL, ROC analysis

## Introduction

Brucellosis is a zoonotic and multisystemic disease that is common all over the world and can occur with specific organ involvements of many systems.[1] The causative agent of the disease is Brucella, a facultatively aerobic, non-spore and capsule-free, gram-negative, non-motile bacillus. There are three pathogenic species for humans: *Brucella abortus, Brucella melitensis, Brucella suis*.[2] In the presence of risk factors such as unpasteurized dairy products, contact with animals, and/or occupational exposure, fever, night sweats, malaise, and arthralgia are the most prevalent symptoms or indicators of brucellosis.[3] The incubation period can be as short as three days or as long as several weeks or even months, while symptoms usually appear 2 to 8 weeks after infection, with acute cases appearing on average 10 to 14 days later.[3,4] One of the most common forms of focal brucellosis is genitourinary involvement.[3] Renal abscess, glomerulonephritis, epididymo-orchitis, pyelonephritis, interstitial nephritis, exudative cystitis, and prostatitis have been reported due to

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brucellosis. Brucellosis of the urinary tract often causes nonspecific symptoms and is therefore underdiagnosed and underreported.[5] Brucellosis with renal involvement may present like chronic and acute interstitial nephritis or glomerulonephritis.[6] Nephrotic syndrome cases have been reported during acute brucellosis.[7] Systemic brucellosis may be linked to acute kidney damage; hemolytic-uremic syndrome; nephrotic syndrome or nephropathies, interstitial nephritis mimicking renal tuberculosis, recurrent immunoglobulin A (IgA) nephropathy, and renal abscess; and various other types of glomerulonephritis, such as chronic interstitial and mesangiocapillary glomerulonephritis, membranoproliferative glomerulonephritis. Other type of kidney disease caused by brucellosis include acute renal failure.[8]

NGAL is one of the most studied biomarker of acute kidney injuries.[9] KIM-1 has been reported as a sensitive biomarker for chronic proximal-tubular damage.[10] It has been reported that KIM-1 levels in acute kidney injury correlate with chronic renal failure in children and adults.[11–13] Tubular and glomerular functions have been shown to be impaired in pediatric brucellosis patients.[14] In the literature, we did not encounter any study evaluating NGAL and KIM-1 markers in the evaluation of renal damage in brucellosis patients and explaining the relationship in etiopathogenesis. Therefore, in this study, the relationship between NGAL and KIM-1, which are important renal biomarkers for the renal functions evaluation in brucellosis patients, and kidney functions was investigated.

# Materials and Methods

## Ethical Approval

Our prospective study was initiated by obtaining the necessary approval from the Mardin Artuklu University Non-Interventional Clinical Research Ethics Committee with the number 2023/4-3. Our study complies with the Declaration of Helsinki. And Informed Consent Form (signed) were obtained from all patients.

## Study Population

60 adult brucellosis patients who were diagnosed with brucellosis with positive agglutination and clinical findings in 2023 from the Infectious Diseases Service and Polyclinic of Mardin Training and Research Hospital and 60 healthy adults with similar demographic characteristics but not diagnosed with brucellosis in the same institution during the same period were included in the study as a control group. The study was conducted with positive agglutination and clinical findings, blood, collection materials, and material obtained during routine examination, testing, analysis and treatment procedures. The obtained materials were kept in a deep freezer at −80 °C till the day of the study and KIM-1 and NGAL levels were studied in serum samples.

### Research Exclusion Criteria

The study excluded participants with acute and known history of chronic diseases, diabetes mellitus, rheumatological disorders, anemia, thyroid and pre-existing chronic kidney disease, hypertension, antioxidant agent usage, trauma, autoimmune illnesses, and local-systemic inflammation.

## Diagnosis

Suitable bacteria were isolated from a blood sample with titers ≥1:160 and/or serum agglutination test, together with clinical symptoms and signs identified by ELISA for the presence of specific IgM antibodies against brucella, the diagnosis of acute brucella infection was made.[15]

Biochemical markers such as KIM-1, NGAL, urea, blood urea nitrogen (BUN), glucose, creatinine, albumin, alanine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), total protein (TP) were assessed in this study. Age and gender were recorded as demographic data.

Serum KIM-1 and NGAL levels were measured using commercially available enzyme-linked immunosorbent assay kits (BTLAB, Shanghai Korain Biotech Co., Ltd). Absorbance was read at 450 nm and recorded using an absorbance microtiter plate reader (ELx800TM; BioTek Instruments, USA). Serum urea, glucose, creatinine, albumin, BUN, ALT, ALP, AST, GGT, and TP levels were determined by routine colorimetric methods on an autoanalyzer (Roche Modular Autoanalyzer; Roche, Tokyo, Japan).

## Statistical Analysis

SPSS software (version 27) was used to conduct the statistical analysis of the data. Shapiro–Wilk tests and Kolmogorov Smirnov were applied to all numerical variables to evaluate whether the data showed normal distribution. It was determined that none of the variables KIM-1, NGAL, glucose, albumin, urea, BUN, creatinine, ALT, AST, TP, ALP and GGT showed normal distribution ($p<0.05$). For the age variable, it was observed that the normal distribution assumption was not provided according to the Shapiro–Wilk test, which is a more powerful test, especially considering the small sample size ($p<0.001$). Therefore, these factors were compared between the brucellosis and healthy groups using the nonparametric Mann–Whitney *U*-test. Since a normal distribution assumption about the data's distribution is not necessary for the Mann–Whitney *U*-test, it was accepted as a more appropriate analysis method in our research. To assess how gender and brucellosis are related, the Pearson Chi-Square test, which is appropriate for testing the significance of the relationship between two categorical variables, was used.

In this study, given the non-normal distribution of the data in our sample of 120 participants, the association between biochemical markers and brucellosis was assessed using Spearman's rank correlation analysis. This non-parametric test is suitable for evaluating the monotonic relationship between a continuous marker and a dichotomous outcome like disease status (Yes/No). The correlation analysis results are presented with coefficients (rho) and p-values, with $p < 0.05$ considered statistically significant. The diagnostic performance of NGAL and KIM-1 in diagnosing brucellosis was assessed using receiver operating characteristic (ROC) curve analysis. The findings are presented visually using tables and figures.

# Results and Discussion

Demographic characteristics of the control and patient groups in our study are summarized in Table 1. The number of male and female included in the study was equal in both groups (control: n=28 female, n=32 male; patients: n=28 female, n=32 male). The mean age of the control group was 38.13 ± 7.099, while the mean age of the patient group was 37.83 ± 7.715. These findings (Table 1) indicate that the distribution of age and gender does not differ statistically significantly between the groups. Similar findings were observed in a research on brucellosis patients, which found no statistically significant difference between gender and age.[1,16] To determine if brucellosis and gender are related, the Pearson Chi-square test was used. Our analysis results showed that there is no statistically significant relationship between brucellosis and gender ($\chi^2 = 0$, df = 1, p = 1.000). Contrary to our data, a study conducted in Iran reported that the rate of brucellosis

**Table 1** Demographic Characteristics of the Study Participants

| Variable | Group | Category/Statistics | Frequency |
|---|---|---|---|
| **Gender** | Control | Female | 28 (46.7%) |
| | | Male | 32 (53.3%) |
| | Brucellosis | Female | 28 (46.7%) |
| | | Male | 32 (53.3%) |
| **Age** | Control | Mean ± SD | 38.13 ± 7.099 |
| | | Min. | 22 |
| | | Max. | 51 |
| | Brucellosis | Mean ± SD | 37.83 ± 7.715 |
| | | Min. | 21 |
| | | Max. | 52 |


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**Table 2** Comparison of Biochemical Biomarkers of Controls and Brucellosis Patients

| Biomarkers | Control (Mean ± SD) | Brucellosis (Mean ± SD) | p |
|---|---|---|---|
| KIM-1 (ng/mL) | 1.90 ± 0.85 | 3.67 ± 2.68 | <0.001* |
| NGAL (ng/mL) | 70.06 ± 18.49 | 180.14 ± 144.78 | <0.001* |
| Glucose (mg/dL) | 93.37 ± 9.56 | 129.00 ± 77.38 | <0.001* |
| Urea (mg/dL) | 13.60 ± 2.84 | 15.43 ± 3.01 | 0.034* |
| BUN (mg/dL) | 29.10 ± 6.07 | 33.03 ± 6.45 | 0.034* |
| Creatinine (mg/dL) | 0.83 ± 0.18 | 0.85 ± 0.18 | 0.515 |
| ALT (U/L) | 11.33 ± 4.10 | 8.70 ± 2.95 | 0.008* |
| AST (U/L) | 17.27 ± 5.60 | 18.03 ± 13.10 | 0.513 |
| ALP (U/L) | 61.67 ± 22.60 | 65.30 ± 34.36 | 0.830 |
| Albumin (g/dL) | 3.92 ± 0.38 | 3.85 ± 0.31 | 0.744 |
| TP (g/dL) | 5.99 ± 0.46 | 5.82 ± 0.49 | 0.189 |
| GGT (U/L) | 27.33 ± 13.80 | 40.03 ± 57.67 | 0.382 |

**Note**: *p < 0.05.

in women is higher than in men.[17] This result shows the difference in the incidence of brucellosis between genders according to region and country.

Brucellosis can cause renal involvement at rates higher than known. Tubular and glomerular diseases are the most common diseases encountered in nephrology practice, but in some cases, differentiation is difficult because what starts in one can affect the other or the same disease can start in both. The results of descriptive statistics and intergroup comparisons of biochemical markers in the control and brucella patient groups of our study are presented in Table 2. NGAL, a member of the lipocalin family, and KIM-1, a type-1 transmembrane glycoprotein, are new and important biomarkers for detecting the early onset of acute renal damage. According to our results, The brucellosis group's KIM-1 and NGAL levels were found to be statistically substantially greater than those of the control group ($p<0.05$). Similarly, The brucellosis group had statistically significant higher levels of urea and glucose ($p<0.05$).

Renal damage can also be diagnosed by the observed increases in BUN and creatinine levels. In our study, BUN levels were found to be statistically significantly higher in the brucellosis group than in the control ($p<0.05$), while no significant difference was observed in creatinine levels between the groups (Table 2). In a study, it was reported that the increased BUN and creatinine values of a brucellosis patient improved significantly and almost returned to normal on the 5th day after 4 days of antibiotic treatment.[18]

According to the results of our study, although AST, ALP, GGT, albumin, and TP indicators did not substantially differ across the groups, ALT levels were shown to be statistically considerably higher ($p<0.05$) in the brucellosis group than in the control (Table 2). One research indicated that patients with brucellosis had elevated levels of ALT, AST, and GGT.[19] Similarly, in another study conducted on 332 pediatric brucellosis patients, in comparison to the control group, the brucellosis group's AST, ALT, and GGT levels were shown to be considerably higher.[20] Transaminase elevations have also been observed in other prospective studies of brucellosis cases.[21,22] Other studies[23,24] evaluating cases diagnosed with brucellosis also found that ALT and AST levels of the patients were high.

The association between brucellosis and KIM-1 and NGAL was assessed using Spearman rank correlation analysis. There was a strong positive connection between brucellosis and both KIM-1 and NGAL (rho = 0.420 and rho = 0.580, $p < 0.001$, respectively) (Table 3). These findings suggest that KIM-1 and NGAL are associated with brucellosis and that the levels of these markers may be elevated in the presence of the disease.

**Table 3** Spearman's Rank Correlation Coefficients for KIM-1, NGAL and, Brucellosis

| | | | KIM-1 | NGAL | Brucellosis |
|---|---|---|---|---|---|
| Spearman's rho | KIM-1 | Correlation Coefficient | 1.000 | 0.720** | 0.420** |
| | | p | | 0.000 | 0.001 |
| | | N | 120 | 120 | 120 |
| | NGAL | Correlation Coefficient | 0.720** | 1.000 | 0.580** |
| | | p | 0.000 | | 0.000 |
| | | N | 120 | 120 | 120 |

**Note**: **p < 0.001.

KIM-1 exhibited a moderate positive correlation (rho (Spearman rank correlation coefficient) = 0.420, p = 0.001) with brucellosis. This result suggests that the increase in KIM-1 levels may be associated with an increased risk of brucellosis infection. More strikingly, a strong positive correlation (rho = 0.580, p < 0.001) was detected between NGAL and brucellosis (Table 3). This finding supports the hypothesis that NGAL may be an important biomarker reflecting the presence or severity of brucellosis infection. The strong association of KIM-1 and NGAL

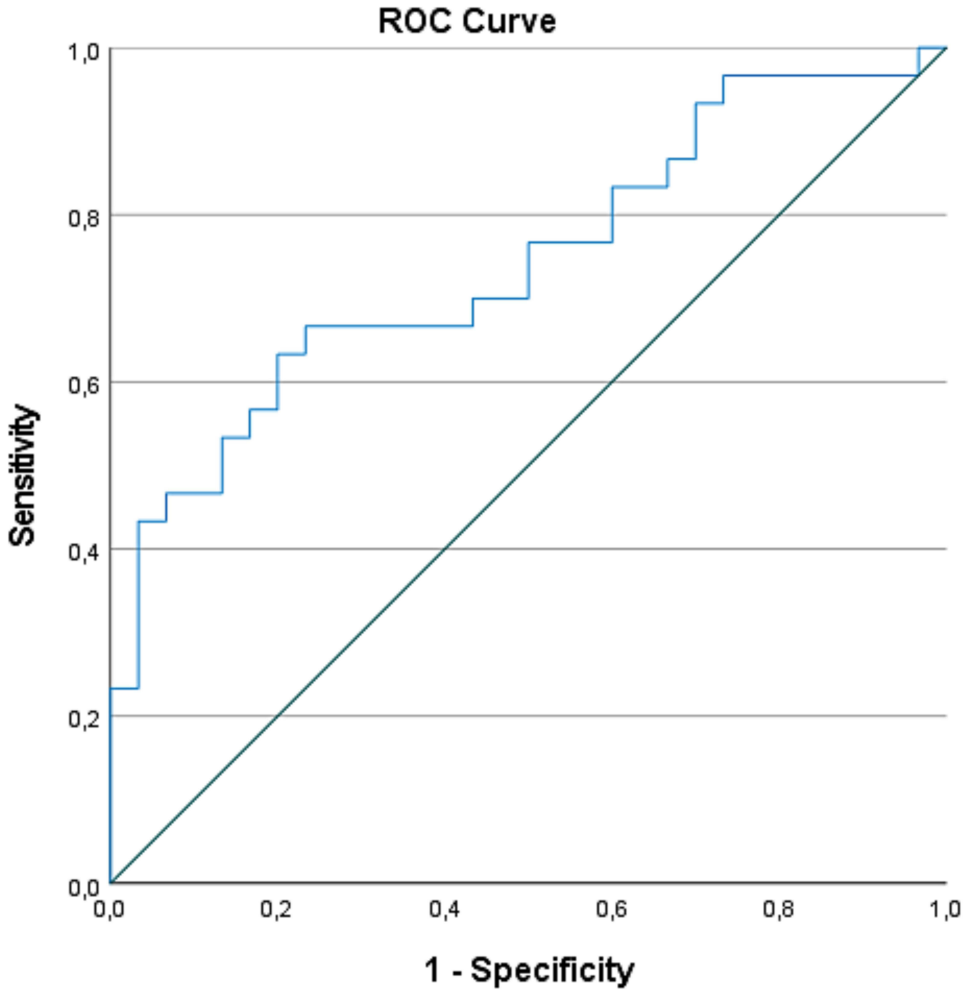


**Figure 1** ROC for KIM-1 in the diagnosis of brucellosis.


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**Table 4** ROC Curve Analysis Results for KIM-1

| Test Variable | Area Under the Curve (AUC) | Standard Error | p-value | 95% Confidence Interval |
|---|---|---|---|---|
| KIM-1 | 0.742 | 0.064 | 0.001 | 0.616–0.868 |

with brucellosis suggests that these markers could potentially be used in the diagnosis and follow-up of the disease. However, more comprehensive, prospective studies are needed to confirm these preliminary findings and to use them in clinical practice. These studies should investigate the role of KIM-1 and NGAL in the pathophysiology of Brucella infection in more detail and determine the diagnostic and prognostic value of these markers. A study[25] reported that delays in diagnosis and treatment increase the likelihood of developing complications. Therefore, lowering the risk of chronicity and recurrence requires early diagnosis and adequate therapy.

Our study also showed that there was a positive correlation between glucose and brucella (rho = 0.466, $p < 0.001$), while a negative correlation between ALT and brucella (rho = −0.345, p = 0.007) (Table 2). However, demographic factors such as age and gender were not found to have a significant relationship with brucella disease.

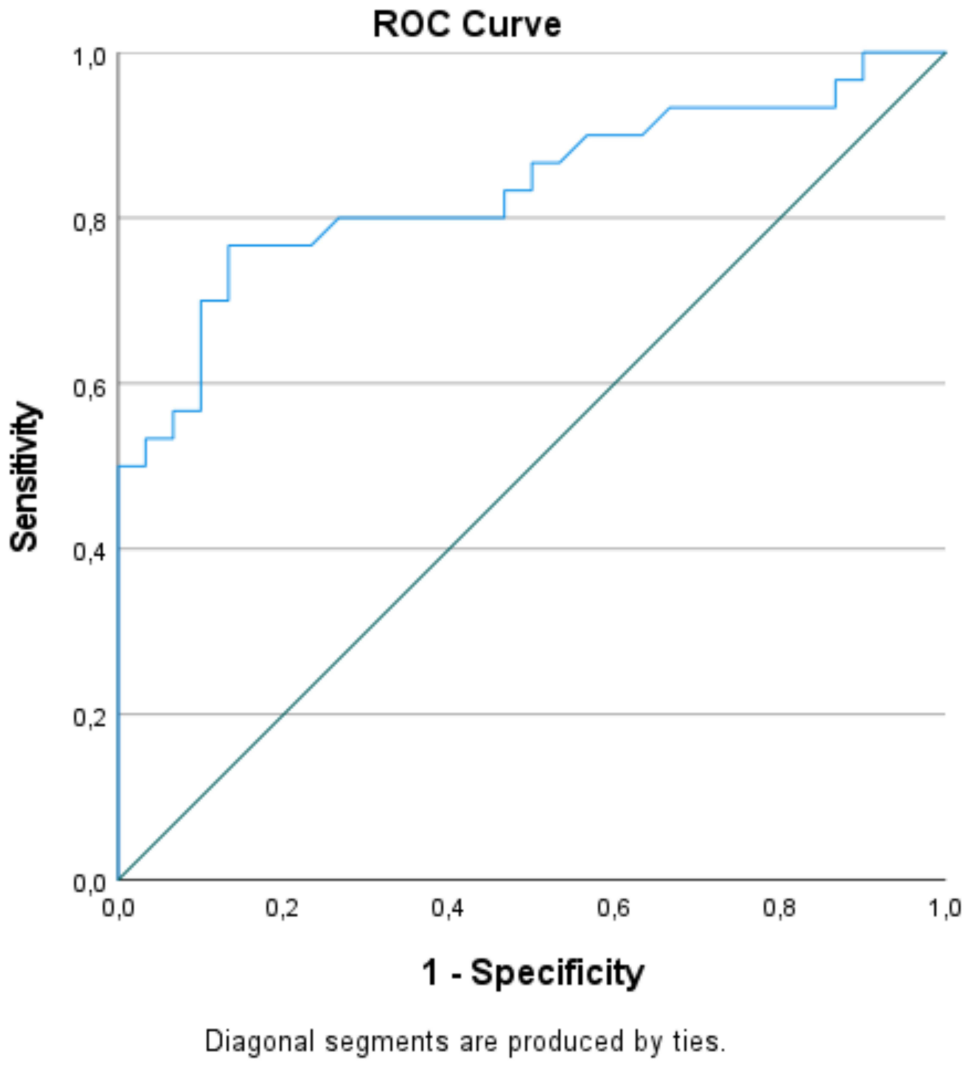


**Figure 2** ROC for NGAL in the diagnosis of brucellosis.

**Table 5** ROC Curve Analysis Results for NGAL

| Test Variable | Area Under the Curve (AUC) | Standard Error | p-value | 95% Confidence Interval |
|---|---|---|---|---|
| NGAL | 0.835 | 0.054 | 0.000 | 0.729–0.941 |

In our analyses, an excellent correlation (rho = 1.000, $p < 0.001$) was found between BUN and urea (Table 2), indicating that the two parameters reflect clinically similar information. In future studies, it is recommended to use only one of these two parameters to avoid multicollinearity.

Confirmation of brucellosis requires exposure history, clinical results and special laboratory tests, examination of predictive biomarkers and examination of effective assays, so ROC analysis is important. ROC curve analysis was carried out to assess the discriminatory power of KIM-1 for the diagnosis of brucellosis (Figure 1). The area under the curve (AUC) for KIM-1 was found to be 0.742 (Table 4). This value is significantly higher than 0.5 ($p = 0.001$), indicating that KIM-1 has moderate accuracy in distinguishing patients with Brucellosis from healthy individuals. The 95% confidence interval is between 0.616 and 0.868, supporting the reliability of these results.

Since brucellosis harms patients and their families and imposes a heavy economic burden on the whole society, it is very important to investigate the definitive biomarkers as comprehensive diagnostic indicators for complicated brucellosis with appropriate techniques. Therefore, ROC curve analysis was performed to evaluate the discriminatory power of NGAL for the diagnosis of brucellosis (Figure 2). The AUC value for NGAL was found to be 0.835 (Table 5). This value is significantly higher than 0.5 ($p < 0.001$), indicating that NGAL has good accuracy in distinguishing brucellosis patients from healthy individuals. The 95% confidence interval is between 0.729 and 0.941, supporting the reliability of these results.

## Conclusion

Delayed diagnosis is a common condition and can be seen in various brucellosis complications that will enter the differential diagnosis of many diseases. Therefore, effective management and treatment of brucellosis depend heavily on an early and precise diagnosis. Since complications are frequently seen in brucellosis patients, we can conclude that monitoring parameters such as NGAL and KIM-1 in patients with delayed diagnosis and underlying diseases at their first hospital admission can facilitate diagnosis and treatment. In our literature search, we did not find any studies conducted with KIM-1 and NGAL biomarkers in brucellosis patients. In this respect, our study is the first clinical study conducted, which made our study valuable. Our study showed that KIM-1 and NGAL levels, markers of renal tubular damage, are higher in patients with brucellosis. In conclusion; the findings and analysis results of our study will be important for clinicians to standardize comprehensive diagnostic warning signs for complex brucellosis to aid in the diagnosis and treat the disease quickly and accurately.

## Data Sharing Statement

The authors declare that all data supporting the findings of this study are available within the paper. Moreover, the datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

## Acknowledgment

The study was approved by the Mardin Artuklu University Non-Interventional Clinical Research Ethics Committee with the ethics committee number *2023/4-3*. Informed Consent Form (signed) were obtained from all patients.

## Disclosure

The authors report no conflicts of interest in this work.

## References

1. Kiymaz YC, Sungur MA. Evaluation of risk factors determining focal organ involvement in patients diagnosed with brucellosis. *Klimik Derg*. 2024;37(3):161–167. doi:10.36519/kd.2024.4855

2. Atluri VL, Xavier MN, de Jong MF, den Hartigh AB, Tsolis RM. Interactions of the human pathogenic brucella species with their hosts. *Annu Rev Microbiol*. 2011;65(1):523–541. doi:10.1146/annurev-micro-090110-102905
3. Bosilkovski M. *Brucellosis: Epidemiology, Microbiology, Clinical Manifestations, and Diagnosis*. UpToDate; 2024.
4. Hayoun MA, Muco E, Shorman M. Brucellosis. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing Copyright © 2022, StatPearls Publishing LLC.; 2022.
5. Stamatiou K, Polyzois K, Dahanis S, et al. *Brucella melitensis*: a rarely suspected cause of infections of genitalia and the lower urinary tract. *Braz J Infect Dis*. 2009;13(2):86–89. doi:10.1590/s1413-86702009000200003
6. Onaran M, Sen I, Polat F, et al. Renal brucelloma: a rare infection of the kidney. *Int J Urol*. 2005;12(12):1058–1060. doi:10.1111/j.1442-2042.2004.01207.x
7. Sabanis N, Gavriilaki E, Paschou E, et al. Renal manifestations of human brucellosis: first report of minimal change disease. *Saudi J Kidney Dis Transpl*. 2016;27(3):590–594. doi:10.4103/1319-2442.182413
8. Anthony Kodzo-Grey V. Brucellosis associated with kidney injury and any form of nephropathy- a review of the literature. *Hamdan Med J*. 2016;9 (3):251–264. doi:10.7707/hmj.447
9. Singer E, Markó L, Paragas N, et al. Neutrophil gelatinase-associated lipocalin: pathophysiology and clinical applications. *Acta Physiol*. 2013;207 (4):663–672. doi:10.1111/apha.12054
10. Gardiner L, Akintola A, Chen G, et al. Structural equation modeling highlights the potential of Kim-1 as a biomarker for chronic kidney disease. *Am J Nephrol*. 2012;35:152–163. doi:10.1159/000335579
11. Carter JL, Parker CT, Stevens PE, et al. Biological variation of plasma and urinary markers of acute kidney injury in patients with CKD. *Clin Chem*. 2016;62(6):876–883. doi:10.1373/clinchem.2015.250993
12. Waikar SS, Sabbisetti V, Arnlov J, et al. Chronic kidney disease biomarkers consortium investigators. relationship of proximal tubular injury to chronic kidney disease as assessed by urinary kidney injury molecule-1 in five cohort studies. *Nephrol Dial Transplant*. 2016;31(9):1460–1470. doi:10.1093/ndt/gfw203
13. Castillo-Rodriguez E, Fernandez-Prado R, Martin-Cleary C, et al. Kidney injury marker 1 and neutrophil gelatinase-associated lipocalin in chronic kidney disease. *Nephron*. 2017;136(4):263–267. doi:10.1159/000447649
14. Conkar S, Kosker M, Cevik S, et al. Association of brucellosis with renal tubular and glomerular damage in children in Turkey. *Saudi J Kidney Dis Transpl*. 2018;29(2):284–289. doi:10.4103/1319-2442.229288
15. Franco MP, Mulder M, Gilman RH, et al. Human brucellosis. *Lancet Infect Dis*. 2007;7(12):775–786. doi:10.1016/S1473-3099(07)70286-4
16. Hasibi M, Jafari S, Mortazavi H, et al. Determination of the accuracy and optimal cut-off point for ELISA test in diagnosis of human brucellosis in Iran. *Acta Med Iran*. 2013;51(10):687–692. PMID: 24338140.
17. Yektay S, Alimi R, Attarian F, et al. Brucellosis and associated risk factors, spatial distribution and cluster analysis: case study in Khorasan Razavi Province, Iran. *J Infect Public Health*. 2025;18(6):102747. doi:10.1016/j.jiph.2025.102747
18. Dagli O, Dokur M, Guzeldag G, Ozmen Y. Acute renal failure due to Brucella melitensis. *J Infect Dev Ctries*. 2011;5(12):893–895. doi:10.3855/jidc.1442
19. Sabancilar I, Sahin IH, Mermutluoglu C, et al. Evaluation of vitamin D, ferritin, folic acid and biochemical levels of brucellosis patients. *Dicle Med J*. 2023;50(4):587–593. doi:10.5798/dicletip.1412118
20. Kazanasmaz H, Geter S. Investigation of the sensitivity and specificity of laboratory tests used in differential diagnosis of childhood brucellosis. *Cureus*. 2020;12(1):e6756. doi:10.7759/cureus.6756
21. Demir MI, Kader C, Colak NY, et al. Evaluation of brucellosis cases. *Bozok Med J*. 2017;7(3):47–51.
22. Kis TT, Kis M, Kose S. Evaluation of etiology, clinical course and complications of 111 brucellosis cases; a retrospective study. *Mersin Univ Saglik Bilim Derg*. 2020;13(3):339–347. doi:10.26559/mersinsbd.774799
23. Demiroglu YZ, Turunc T, Aliskan H, et al. Brucellosis: retrospective evaluation of the clinical, laboratory and epidemiological features of 151 cases. *Mikrobiyol Bul*. 2007;41(4):257–517.
24. Ibak G, Hamdi S, Onur K, et al. Brucellosis: evaluation of 201 cases in an endemic area of Mediterranean Basin. *Acta Med Mediterr*. 2014;30:121.
25. Shi QN, Qin HJ, Lu QS, et al. Incidence and warning signs for complications of human brucellosis: a multi-center observational study from China. *Infect Dis Poverty*. 2024;13(1):18. doi:10.1186/s40249-024-01186-4