

ARGINASE ACTIVITY IN SERUM AS INDICATOR OF OSTEOARTHRITIS SEVERITY IN PATIENTS

Z. M. A. A. HAMODAT^{1✉}, M. A. IBRAHIM², O. M. YAHYA²

¹Department of Chemistry, College of Science, University of Mosul, Iraq;

²Department of Biochemistry, College of Medicine, University of Mosul, Iraq

✉ e-mail: zahraahodat@uomosul.edu.iq

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Osteoarthritis (OA) is a chronic degenerative disease of the joints that represents the second most common rheumatic disease after rheumatoid arthritis. Arginase, a multifunctional enzyme that plays an important role in disease development, and adenosine deaminase, which is involved in the immune response, are considered to be involved in the pathogenesis of osteoarthritis. The study aimed to estimate both the activity of arginase and adenosine deaminase in the serum of patients with osteoarthritis depending on disease severity, age, and body mass index (BMI). The study included 80 participants, 40 in the control group and 40 with OA, divided into groups with mild or severe degrees of the disease, aged 30-45 and 46-65, with normal or overweight BMI. Enzyme activity was measured colorimetrically. Patients with severe osteoarthritis exhibited a significantly increased level of the activity for both arginase and adenosine deaminase compared to patients with mild osteoarthritis and healthy individuals. A strong positive correlation between the activity of arginase and age was found in the severe group, whereas a weak correlation was found between the activity of arginase and BMI in both mild and severe OA groups. ROC curve analysis showed that arginase exhibited an exceptionally high area under the curve (AUC of 0.923), indicating that arginase has high specificity and sensitivity compared to adenosine deaminase and other indicators in distinguishing between patients with osteoarthritis and healthy individuals.

Key words: arginase, adenosine deaminase, osteoarthritis, disease severity, patient's age and body weight.

Osteoarthritis (OA) is a chronic degenerative disease of the joints that leads to significant morbidity, physical disability, and decreased quality of life [1, 2]. It is characterized by pain when moving and loss of cartilage, finally leading to obstruction of movement [3, 4]. After rheumatoid arthritis (RA), osteoarthritis is considered the second rheumatic disease. It is a chronic degenerative disease of the joints that represents the second most common rheumatic disease [5, 6]. The prevalence rate reaches tens of millions in the United States alone, and estimates indicate that approximately 300 million people around the world have radiographic evidence of osteoarthritis [7]. OA develops, the balance shifts towards the deterioration of the joint tissues and leads to the development of synovial inflammation, and the formation of osteophytes, including joint pain, stiffness, crepitus, blurring, and decreased movement [8]. The pathogenesis of OA has been reported to have three stages depending on the severity of the disease [9]. Studies

in the literature indicate that women have a higher prevalence of osteoarthritis, and it increases after 50 years of age [10, 11]. Arginase (EC 3.5.3.1) works to stimulate the final step of the urea cycle, which is one of the hydration enzymes by converting L-arginine into L-ornithine and urea, and rids the body of ammonia toxicity, as it plays an important role in the metabolism and formation of urea. Moreover, obesity doubles the risk of developing symptoms of osteoarthritis. Adenosine deaminase serves as a checkpoint for regulating the level of extracellular adenosine, thus potentially modifying inflammatory processes. Thus, although the level of adenosine deaminase may be evaluated as a suitable technique of assessing the Severity of RA, it seems that adenosine deaminase may be a predictive indicator of inflammatory processes in RA [12, 13]. It is considered a biomarker for immune disease [14]. Our study aims to investigate arginase as a biomarker indicator for disease severity of osteoarthritis.

Materials and Methods

The current study was conducted from August 1 to December 2023.

Population study. The study included 80 participants, whose ages ranged from 30 to 65 years: 40 osteoarthritis patients (24 females, 16 males) and 40 healthy controls (23 females, 17 males). The samples of patients were collected from the patients who attended the outpatient clinics of the joint unit at Ibn Sina Teaching Hospital in Mosul, Iraq. At the same time, OA patients were divided according to disease severity into two groups: 18 patients with mild disease and 22 with severe disease, based on the radiological outcome of X-ray, clinical, and physical examination performed by a specialist physician. Inclusion criteria of the patient group included their age between 30 and 65 years, with confirmed osteoarthritis diagnosed through radiographic and clinical examination by a specialist physician. Moreover, the inclusion criteria of controls reveal apparently healthy adults with no history of osteoarthritis or inflammatory joint diseases and matched age. Exclusion criteria of both groups included a medical history of other types of arthritis, inflammatory or autoimmune joint diseases, cancer, kidney disease, thyroid disorders, or other conditions. The study protocol was approved according to a formal approval (Approval No. 24371; Date: 30/06/2024) obtained for the study protocol for the research project entitled "Arginase as a Biomarker for the Severity of Arthritis" at Ibn Sina Teaching Hospital. This approval was granted by the Nineveh Health Directorate, Training and Human Development Center, Mosul, Iraq. Approval was granted to proceed with the research project. In accordance with the Declaration of Helsinki of 1964 and its subsequent amendments, all procedures performed in this study complied with the ethical standards of the Institutional Research Committee. Furthermore, written informed consent was obtained from all participants before sample collection.

Sample collection. Five ml of blood was drawn and placed in a clean gel tube, then left at 37°C for about 15 min. Serum was separated after centrifuging at a speed of 3000 xg for five minutes and put into clean and sterile containers and stored at -20°C until measurements were performed [2].

Estimation of arginase activity. Arginase activity was determined according to Kocna P. et al. This method relies on the enzyme's ability to convert arginine to ornithine and urea. Arginase activi-

ty is estimated by measuring the amount of ornithine produced, and the enzyme itself is measured by measuring ornithine levels [15].

Estimation of adenosine deaminase activity. Adenosine deaminase activity was measured using a colorimetric method according to Giusti [16]. The principle of the method of the assay of adenosine deaminase activity included the conversion of adenosine to inosine, resulting in the formation of ammonia.

Estimating the body mass index (BMI). BMI was measured by dividing weight by the square of height and expressed as kg/m² [17].

Statistical analysis. A statistical analysis was performed using SPSS version 25. An independent t-test is used to compare two groups, and an independent to compare more than two groups. Followed by a Duncan test to identify significant differences between group means. Pearson's correlation coefficient was used to explore the correlation between the activity of arginase and the variable studied. Also, receiver operating characteristic (ROC) curve analysis was performed to assess the diagnostic performance of the parameters studied, and results were reported with 95% confidence intervals. A *P*-value of less than 0.05 was considered statistically significant [18].

Result and Discussion

Study of the characteristics of arginase activity level in osteoarthritis patients compared to controls. Table 1 shows the characteristics of arginase activity level in OA patients, including a comparison of the arginase activity between OA patients and controls, and studying the effect of risk factors for the osteoarthritis disease, including age, sex, and obesity. The results showed a significant increase in arginase activity in OA patients (35.8 ± 16.6 U/ml; $P \leq 0.0001$) compared to the control group (14.7 ± 10.5 U/ml). These results agree with [19]. These results indicate that increased arginase activity may be associated with worsening of osteoarthritis symptoms [20]. Also, a significant increase in arginase activity was observed with age in both patients and the control group. In the control group, arginase activity level ranged from 11.6 ± 2.4 U/ml (age group 30–45 years) to 16.4 ± 4.0 U/ml (age group 46–65 years), with a significant difference ($P \leq 0.001$). Also, OA patients, the age factor affects them more than the controls, although there are no significant differences. Arginase activity for OA patients ranged from 24.4 ± 5.6 U/

ml (age group 30–45 years) to 40.0 ± 17.4 U/ml (age group 46–65 years), with a significant difference ($P \leq 0.0001$). These results suggest that aging may be associated with increased arginase activity in both patients and healthy controls, but in OA patients higher. Moreover, no significant differences ($P = 0.34$) for arginase activity were observed between females and males in both patients and the control group. In the control group, arginase activity was 15.0 ± 4.4 U/ml in females and 14.1 ± 6.9 U/ml in males, with no significant difference ($P = 0.34$). Also, for patients, arginase activity of females was 36.2 ± 16.0 U/ml higher than that of males, 35.9 ± 19.2 U/ml, also with no significant difference ($P = 0.9$). These results suggest that gender may not have a considerable effect on arginase activity in both OA patients and healthy subjects, although females have higher arginase activity than males. Additionally, as shown in Table 1, no significant differences in arginase activity were observed between obesity categories (normal weight, overweight, and obese) in both control and patients. In the control group, arginase activity value was 12.0 ± 7.2 U/ml for normal weight, 13.7 ± 7.6 U/ml for overweight, and 14.4 ± 8.9 U/ml for obese, with no significant difference. In patients, arginase activity level was 33.0 ± 15.7 U/ml for normal weight, 36.2 ± 16.3 U/ml for overweight, and 36.4 ± 19.0 U/ml for obesity, with no significant difference. These results suggest that obesity may not be associated with significant changes in arginase activity in both patients and healthy subjects. Despite arginase activity increasing along with increasing of obesity, which means that obesity affects arginase activity [21, 22].

Study of the characteristics of adenosine deaminase activity in osteoarthritis patients compared to the control group. Table 2 presents a study of adenosine deaminase activity (ADA) in patients with osteoarthritis compared to the control group. The study also examined the effect of osteoarthritis risk factors, such as age, sex, and obesity. The results showed a significant difference in ADA activity between the two groups. Osteoarthritis patients exhibited a significantly higher mean activity (33.3 ± 9.2 U/ml, $P \leq 0.0001$) compared to the control group (19.5 ± 8.5 U/ml), indicating a highly significant difference. According to age, no statistically significant differences in ADA activity were observed in either group. In the control group, ADA activity was similar across the 30–45 and 46–65 age groups ($P = 0.28$), while in osteoarthritis patients,

ADA levels were also similar across these two age groups ($P = 0.745$). Furthermore, gender did not appear to affect ADA enzyme activity in either patients or healthy individuals, with a P -value of 0.691 for the control group and 0.549 for patients. Moreover, regarding obesity, ADA enzyme activity tended to increase with increasing BMI in both groups. In the control group, ADA enzyme activity was lowest in individuals of normal weight (16 ± 2.7 U/ml), highest in overweight individuals (19.5 ± 7.6 U/ml), and highest in obese individuals (20.5 ± 11.6 U/ml). No P -values were provided for statistical significance. Similarly, in the osteoarthritis patient group, ADA enzyme activity increased with increasing body mass index (BMI), with the highest levels recorded in obese individuals (37.4 ± 10.1 U/ml), followed by overweight individuals (33.24 ± 9.2 U/ml), and then individuals of normal weight (31.9 ± 6.0 U/ml). Overall, the results indicate that osteoarthritis patients have significantly higher ADA enzyme activity compared to healthy individuals, and that elevated ADA enzyme levels are associated with obesity in both groups. Furthermore, elevated ADA enzyme activity is not affected by age or sex in either the control or patient groups. This suggests that obesity may contribute to increased levels of this enzyme, which could play a role in degenerative arthritis.

Study of the effect of disease severity on the variables studied for patients with OA. The data presented in Table 3 examines the impact of disease severity on several key variables in OA patients. The study involved three groups: a control group (Group A, $n = 40$), patients with mild OA (Group B, $n = 18$), and patients with severe OA (Group C, $n = 22$). The results indicate notable differences in arginase and adenosine deaminase activities across the groups. Arginase activity was significantly higher in the severe OA group (47.6 ± 15.3 U/ml) compared to both the mild OA group (25.1 ± 10.5 U/ml) and the control group (14.7 ± 9.3 U/ml), with P -values of 0.004, 0.0001, and 0.0001, respectively, suggesting a strong association between elevated arginase activity and disease severity. Similarly, adenosine deaminase activity followed a similar pattern, with the severe OA group showing the highest levels (39.2 ± 8.5 U/ml) compared to mild OA (28.2 ± 8.1 U/ml) and control (19.5 ± 6.5 U/ml), all showing significant differences ($P = 0.0001$ for all comparisons). In contrast, there were no significant differences in age and BMI between the groups, with P -values of 0.82, 0.73, and 0.16 for age, and P -values of 0.3, 0.6, and 0.9 for

Table 1. Study of the characteristics of arginase activity for patients with osteoarthritis compared to controls

Variable		Control, n = 40		Patients, n = 40		P-value
Arginase activity, U/ml		14.7 ± 10.5		35.8 ± 16.6***		0.0001
<i>Arginase activity according to age factor</i>						
Control			Patients			
(30-45), n = 23	(46-65), n = 17	P-value	(30-45), n = 24	(46-65), n = 16	P-value	
11.6 ± 2.4	16.4 ± 4.0***	0.001	24.4 ± 5.6	40.0 ± 17.4***	0.0001	
<i>Arginase activity according to sex factor</i>						
Control			Patients			
Female, n = 23	Male, n = 17	P-value	Female, n = 24	Male, n = 16	P-value	
15.0 ± 4.4	14.1 ± 6.9	0.34	36.2 ± 16.0	35.92 ± 19.20	0.9	
<i>Arginase activity according to obesity in the control</i>						
Normal weight BMI (18.5-24.9), n = 9		Overweight BMI (25-29.9), n = 12		Obese (BMI ≥ 30), n = 19		
12.0 ± 7.2 ^a		13.7 ± 7.6 ^a		14.4 ± 8.9 ^a		
<i>Arginase activity according to obesity in the patients</i>						
Normal weight BMI (18.5-24.9), n = 8		Overweight BMI (25-29.9), n = 11		Obese (BMI ≥ 30), n = 21		
33.0 ± 15.7 ^a		36.2 ± 16.3 ^a		36.4 ± 19.0 ^a		

Note. *** Refers to a significant difference at ($P \leq 0.0001$); ^aSimilar letter means non-significant differences; (mean ± SD)

BMI, indicating that these factors did not play a significant role in disease severity. Overall, the findings suggest that while age and BMI remain relatively stable across OA severity levels, the significant increase in enzyme activities in the severe OA group points to the potential role of these enzymes in the progression of osteoarthritis.

As shown in Table 4, the correlation of arginase activity with the studied variables in arthritis patients was examined. The results showed a strong positive correlation between arginase activity and ADA activity in the overall group ($r = 0.615$, $P = 0.001$), indicating that elevated arginase levels are associated with elevated ADA activity. Arginase also showed a strong positive correlation with age in the severely affected group ($r = 0.94$, $P = 0.03$) and a moderate correlation in the overall group ($r = 0.378$, $P = 0.03$), suggesting that age is associated with arginase activity in severe cases. BMI may also have a weak effect on arginase activity. Although weak correlations were found between BMI and arginase activity in both the mild and severe groups, a moderate positive correlation was observed in the overall group ($r = 0.37$, $P = 0.04$). These findings support the importance of ADA activity, age, and BMI as potential factors influencing arginase activity in arthritis patients.

Studying the relationship between arginase activity and the studied variables. The results of the relationship analysis between arginase enzyme activity and selected variables in osteoarthritis patients are shown in Table 4. The results showed a strong positive correlation between arginase activity and age in the severe group ($r = 0.94$, $P = 0.03$), while a moderate positive correlation was found in all patients ($r = 0.378$, $P = 0.03$), indicating that the effect of age on arginase activity is more pronounced in severe cases compared to mild cases. Also, the results showed a strong and significant positive correlation between arginase enzyme activity and ADA activity in all patients. This indicates that increased arginase activity is associated with increased ADA activity, suggesting a correlation between arginine metabolism and inflammatory activity in osteoarthritis. Regarding BMI, a weak and non-significant correlation was observed between BMI and arginase activity in both the mild and severe groups individually, while a moderate and significant positive correlation was found when analyzing all patients ($r = 0.37$, $P = 0.04$), suggesting that obesity may have a limited but significant effect on arginase activity when considering the entire sample. Our study indicates that adenosine deaminase activity and age, and to a lesser extent body mass index, are factors

Table 2. Study of the characteristics of adenosine deaminase activity for patients with osteoarthritis compared to controls

Variable		Control, n = 40		Patients, n = 40		P-value
Adenosine deaminase activity, U/ml		19.5 ± 8.5		33.3 ± 9.2***		0.0001
<i>Adenosine deaminase activity according to age factor</i>						
Control			Patients			
(30-45), n = 17	(46-65), n = 23	P-value	(30-45), n = 19	(46-65), n = 21	P-value	
18.2 ± 5.0	21.7 ± 9.9	0.28	32.5 ± 7.2	33.5 ± 8.0	0.745	
<i>Adenosine deaminase activity according to sex factor</i>						
Control (mean ± SD)			Patients (mean ± SD)			
Female, n = 23	Male, n = 17	P-value	Female, n = 24	Male, n = 16	P-value	
19.9 ± 4.4	19.2 ± 6.9	0.691	33.9 ± 9.7	31.7 ± 9.1	0.549	
<i>Adenosine deaminase activity according to obesity in the control</i>						
Normal weight BMI (18.5-24.9), n = 9		Overweight BMI (25-29.9), n = 11		Obese (BMI ≥ 30), n = 20		
16.0 ± 2.7 ^a		19.5 ± 7.6 ^a		20.5 ± 11.6 ^a		
<i>Arginase activity according to obesity in the patients</i>						
Normal weight BMI (18.5-24.9), n = 11		Overweight BMI (25-29.9), n = 10		Obese (BMI ≥ 30), n = 19		
31.9 ± 6.0		33.24 ± 9.20		37.4 ± 10.1		

Note. ***Refers to a significant difference at ($P \leq 0.0001$); ^aSimilar letter means non-significant differences; (mean ± SD)

Table 3. The effect of disease severity on the variables studied for patients with osteoarthritis

Case variables	Groups			P-value		
	A, Control, n = 40	B, Mild, n = 18	C, Severe, n = 22	A vs B	A vs C	B vs C
Arginase activity, U/ml	14.7 ± 9.3	25.1 ± 10.5***	47.6 ± 15.3***	0.004	0.0001	0.0001
Adenosine deaminase activity, U/ml	19.5 ± 6.5	28.2 ± 8.1***	39.2 ± 8.5***	0.001	0.0001	0.0001
Age, year	47.3 ± 8.4	47.9 ± 8.6	52.3 ± 8.7	0.82	0.73	0.16
BMI, kg/m ²	27.2 ± 4.8	28.6 ± 3.3	28.6 ± 63.7	0.3	0.6	0.9

Note. ***Refers to a significant difference at ($P \leq 0.0001$)

Table 4. Correlation of arginase activity with variables studied in osteoarthritis

Biochemical variable	Arginase activity, U/ml; Pearson correlation (r), P ^o		
	Mild, n = 18	Severe, n = 22	Total/All patients, n = 40
Adenosine deaminase activity, U/ml	0.202; 0.45	0.524; 0.06	0.615**; 0.001
Age, year	0.193; 0.47	0.94***; 0.03	0.378*; 0.03
BMI, kg/m ²	0.115; 0.67	0.18; 0.71	0.37*; 0.04

Note. *Correlation is significant at the 0.05 level; **Correlation is significant at the 0.001 level; ***Correlation is significant at the 0.0001 level; P^o – refer to P-value

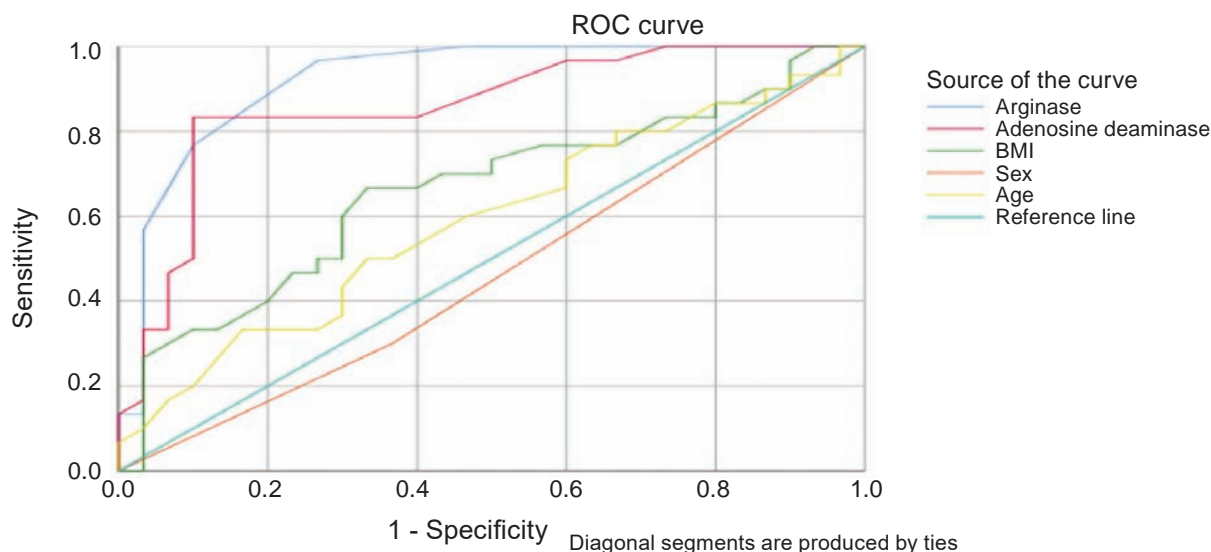


Figure. Receiver operating characteristic (ROC) curve analysis for the arginase and variable studies

Table 5. Receiver operating characteristic (ROC) curve analysis for the arginase and variable studies

Variable	AUC	95% CI
Arginase	0.923	0.86–0.97
ADA	0.859	0.78–0.93
BMI	0.661	0.54–0.77
Age	0.591	0.47–0.70
Sex	0.467	0.35–0.58

Note. AUC – area under the curve; CI – confidence interval

associated with increased arginase activity in osteoarthritis patients, particularly in severe cases [23], with the need to interpret these results with caution due to the sample size.

Receiver operating characteristic (ROC) curve analysis for the arginase and variable studies. The results showed that arginase has superior sensitivity and specificity in distinguishing between patients with and without arthritis. As shown in Figure and Table 5, arginase was identified as a highly promising candidate based on the results provided. Arginase exhibited an exceptionally high area under the curve (AUC) of 0.923, and compared to other indicators such as adenosine deaminase (AUC = 0.859), BMI (AUC = 0.661), sex (AUC = 0.467), and age (AUC = 0.591). This result indicates that arginase has high specificity and sensitivity in distinguishing between patients with osteoarthritis and those without the disease, and more reliable diagnostic tool.

Elevated arginase activity has been associated with changes in arginine metabolism during inflammatory conditions, which may lead to decreased nitric oxide bioavailability and contribute to cartilage degeneration and impaired joint function [20, 24]. Studies have shown similar increases in arginase activity in other inflammatory joint diseases, such as rheumatoid arthritis, supporting its potential role in osteoarthritis.

This study has some limitations that should be acknowledged, including the relatively small sample size and the lack of a full history, systematic, and detailed clinical characteristics for all patients, such as precise radiographic classification systems and disease duration. This may affect arginase activity levels and should therefore be considered when interpreting the results. We also recommend that larger sample sizes be conducted to validate and expand upon the current findings. We also recommend more studies and more comprehensive clinical descriptions. The relatively small sample size, especially after dividing patients into mild and severe groups, may limit the statistical support for the results. Furthermore, regarding this disease, we recommend employing multivariate models and other samples such as synovial fluid to ensure that arginase has independent and reliable diagnostic tool for OA disease.

Conclusion. We conclude from this study that patients with osteoarthritis had significantly higher activity levels of arginase and adenosine deaminase compared to healthy individuals. Also, these

findings suggest that both enzymes may be involved in the inflammatory processes associated with osteoarthritis and could potentially serve as biomarkers for disease presence and degree of disease severity. Notably, patients with severe osteoarthritis exhibited significantly higher levels of arginase and ADA enzyme activity compared to patients with mild osteoarthritis and healthy individuals, supporting a possible link between enzyme activity and disease severity. Furthermore, the observed positive correlation between arginase and ADA activity suggests a possible association between these two enzymes via shared inflammatory or metabolic pathways in the pathophysiology of osteoarthritis. Arginase activity was positively correlated with age, particularly in patients with severe osteoarthritis, indicating that advancing age may contribute to increased arginase activity during disease progression. ROC analysis showed that arginase had superior diagnostic performance compared to adenosine deaminase, age, sex, and obesity, indicating its potential usefulness as a biomarker for differentiating between osteoarthritis patients and healthy individuals. Although the sample size was relatively small, these results should be interpreted with caution. We recommend further studies with larger patient cohorts to confirm the diagnostic value of arginase and its role in disease progression or treatment through arginase inhibition.

Conflict of interest. The authors have completed the Unified Conflicts of Interest form at http://ukr-biochemjournal.org/wp-content/uploads/2018/12/coi_disclosure.pdf and declare no conflict of interest.

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АКТИВНІСТЬ АРГІНАЗИ В СИРОВАТЦІ КРОВІ ЯК ПОКАЗНИК СТУПЕНЯ ТЯЖКОСТІ ОСТЕОАРТРИТУ У ПАЦІЄНТІВ

Z. M. A. A. Hamodat¹✉, M. A. Ibrahim², O. M. Yahya²

¹Department of Chemistry, College of Science, University of Mosul, Iraq;

²Department of Biochemistry, College of Medicine, University of Mosul, Iraq

✉e-mail: zahraahamodat@uomosul.edu.iq

Остеоартрит (ОА) – це хронічне дегенеративне захворювання суглобів, яке посідає друге місце за поширеністю серед ревматичних захворювань після ревматоїдного артриту. Вважається, що в патогенезі остеоартриту залучені аргіназа – багатофункціональний ензим, який відіграє важливу роль у розвитку захворювання, та аденозіндеаміназа, яка бере участь в імунній відповіді. Метою дослідження було визначити активність аргінази та аденозіндеамінази у сироватці крові пацієнтів із остеоартритом залежно від тяжкості захворювання, віку та індексу маси тіла (ІМТ). У дослідженні взяли участь 80 осіб: 40 у контрольній групі та 40 пацієнтів із ОА, розділених на групи за ступенем тяжкості захворювання (легкий або тяжкий), віком 30–45 та 46–65 років, із нормальним або надмірним ІМТ. Активність ензимів вимірювали колориметрично. Пацієнти з тяжким ОА демонстрували значно вищі рівні активності аргінази та аденозіндеамінази порівняно з пацієнтами з легким ОА та здоровими особами. У групі з тяжким перебігом захворювання було виявлено виражену позитивну кореляцію між активністю аргінази та віком, тоді як кореляція між активністю аргінази та ІМТ як у групі з легким, так і з тяжким ОА виявилася слабкою. Аналіз ROC-кривої показав, що аргіназа мала надзвичайно високу площу під кривою (AUC 0,923), що свідчить про її високу специфічність та чутливість порівняно з аденозіндеаміназою та іншими маркерами у визначенні пацієнтів з остеоартритом та здорових осіб.

Ключові слова: аргіназа, аденозіндеаміназа, остеоартрит, тяжкість захворювання, вік та маса тіла пацієнта.

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