ABCResearch

Arch Basic Clin Res 2025;7(3):135-141
DOI: 10.4274/ABCR.2025.25360

Research Article

Correlation of Antenatal and Postnatal Maternal Uterine and Renal Artery Doppler Parameters with Proteinuria in Preeclamptic Pregnant Women

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Cite this article as: Eski Arslan M, Dinç G. Correlation of antenatal and postnatal maternal uterine and renal artery doppler parameters with proteinuria in preeclamptic pregnant women. *Arch Basic Clin Res*. 2025;7(3):135-141.

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ABSTRACT

Objective: To examine the relation between the mother's renal and uterine artery (UA) Doppler parameters before and during birth in preeclamptic pregnant women and the degree of proteinuria.

Methods: In our study, 30 preeclamptic patients diagnosed in our hospital and 30 healthy pregnant women with matched gestational weeks were evaluated. To determine the amount of protein in the urine, 24-hour urine samples were taken from each patient. Doppler examinations of the UA and renal artery (RA) of the mother were carried out. On the seventh postnatal day, the cases were called in for follow-up, and the uterine and RA Doppler parameters were reevaluated. Spearman correlation analysis was used to assess the association between maternal uterine and RA pulsatility index (PI), resistive index (RI) values, and proteinuria.

Results: The preeclampsia group's antenatal right UA artery PI (1.29 ± 0.5) and RI (0.62 ± 0.13) values were observed to be considerably higher than those of the control group, with PI values (1.01 ± 0.43) and RI values (0.54 ± 0.16). Postnatal right UA PI (1.33 ± 0.56) in preeclampsia group was statistically different compared with postnatal UA PI (1.07 ± 0.32) in control group ($P < 0.05$). Postnatal RA PI and RI values were similar in both groups. In preeclamptic patients, right RA PI (1.03 ± 0.29) was statistically higher compared with postnatal RA PI (0.92 ± 0.18). While a significant correlation was found between right UA Doppler parameters and the amount of proteinuria, no correlation was found between RA Doppler parameters and it.

Conclusion: The degree of proteinuria and maternal UA Doppler parameters are significantly correlated. There was no correlation between RA Doppler parameters and the amount of proteinuria.

Keywords: Preeclampsia, proteinuria, renal artery Doppler, uterine artery Doppler, Doppler US

INTRODUCTION

Four to five percent of pregnancies end in preeclampsia (PE), a serious pregnancy complication. Fetal prematurity and maternal long-term cardiovascular problems are a major cause of maternal and fetal morbidity and mortality.[1] Hemorrhagic stroke, hemolysis, elevated liver enzymes, reduced platelets, renal failure, and pulmonary edema are among the possible complications.[2-4] In the second half of pregnancy, PE is linked to newly diagnosed hypertension and frequently proteinuria. PE can potentially affect many organs. However, proteinuria is a defining feature for the diagnosis of PE, and renal alterations are invariably present. Classically, glomerular endothelial damage is thought to be responsible for the renal deterioration that is present in the setting of PE.[5-7] With the progression of PE, profound systemic vasoconstriction occurs, leading to decreases in glomerular filtration (GFR).

It is thought that insufficient trophoblastic invasion plays a role in the pathophysiology of placental diseases in PE instances, although the exact mechanism is still unclear.[8]

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Received: August 15, 2025
Revision Requested: September 4, 2025 **Accepted:** September 12, 2025 **Publication Date:** November 17, 2025

Impaired placental development causes increased vascular resistance in the uteroplacental circulation. This condition causes an increase in pulsatility (PI) and resistive index (RI) in the uteroplacental circulation on Doppler ultrasonography, as well as an abnormal wave pattern in the uterine artery (UA). Therefore, it has been shown that pregnant women who are at risk for PE and intrauterine growth retardation may be evaluated using Doppler ultrasonography as a screening test.[9-11] Endothelial damage, which is involved in the pathogenesis of PE, and the increase in vascular resistance that develops secondary to endothelial damage are the main causes of both proteinuria and decreased renal and UA blood flow.[8-11] Due to the common etiopathogenesis, there is correlation exists between increased vascular resistance and proteinuria in uterine and renal artery (RA) Doppler parameters. The study aims to determine the relationship between proteinuria and UA and RA Doppler parameters in preeclamptic pregnant women.

MATERIAL AND METHODS

The study consisted of 30 preeclamptic pregnant women who were diagnosed with PE during routine examinations and 30 healthy pregnant women as a control group, all of whom presented to the Department of Obstetrics and Gynecology at Karadeniz Technical University Farabi Hospital between February 2020 and September 2020. On January 28, 2020, the Karadeniz Technical University Faculty of Medicine Scientific Research Ethics Committee approved the prospective study using protocol number 2020/35 on 28.01.2020. Written consent is obtained from every patient admitted to the hospital after they read and sign the informed consent form. After the preeclamptic pregnant women in the study group were formed, 30 normal pregnant women of similar age, gestational age, and body mass index were selected as the control group. Patients presenting to our clinic between the ages of 18 and 35, with no systemic disease, no risk factors for pregnancy, and no history of chronic medication use, were considered the control group. Pregnant women who met the study criteria and agreed to participate voluntarily were included as the control group. UA and RA Doppler examinations were also performed in these patients. For comparison with preeclamptic pregnant women, 24-hour urine protein excretion was recorded for each patient, in addition to routine pregnancy blood tests.

MAIN POINTS

- A significant correlation was observed between the degree of proteinuria and maternal uterine artery Doppler parameters.
- Antenatal right uterine artery pulsatility index (PI) and resistive index (RI) values were significantly higher in the preeclampsia group compared with the control group.
- In patients with preeclampsia, antenatal renal artery PI values were statistically higher than postnatal renal artery PI values.
- No significant correlation was found between renal artery Doppler parameters and the degree of proteinuria.

The requirements for inclusion in this research were being beyond the 20th week of pregnancy, not having any known kidney disease, being a volunteer, and having a singleton pregnancy. Pregnant women diagnosed with multiple pregnancy, chronic hypertension, Hemolysis, Elevated Liver Enzymes and Low Platelets syndrome, eclampsia, gestational hypertension, and kidney disease were not included in the study. All patients who were part of the trial filled out informed consent forms. PE was diagnosed according to the American College of Obstetricians and Gynecologists criteria.[12] Accordingly:

1. A woman who has previously had normal blood pressure should have two readings taken at least four hours apart after 20 weeks of pregnancy. The readings should show a systolic blood pressure of greater than 140 mm Hg and a diastolic blood pressure of greater than 90 mm Hg. A systolic blood pressure of 160 mm Hg or a diastolic blood pressure of 110 mm Hg or higher was considered severe PE.

2. Proteinuria: If quantitative techniques are not available, proteinuria is defined as 300 mg or more in 24-hour urine or a protein/creatinine ratio ≥ 0.3 (each in mg/dL) or + 2 protein with dipstick.

3. Thrombocytopenia: less than 100,000 platelets per microliter.

4. Serum creatinine levels above 1.1 mg/dL or a doubling of serum creatinine levels, independent of other renal disorders, are indicative of renal failure.

5. Impaired liver function: Elevation of liver transaminases to doubling of normal concentration.

6. Edema of the lungs.

7. New onset headache that is unresponsive to medication and not associated with other diagnostic or visual symptoms.

Age, body mass index, gravidity, parity, abortion, birth weeks, medications used, and additional disease information were obtained from the cases included in the study. The amount of proteinuria was analyzed by collecting a 24-hour urine sample. UA and RA Doppler examinations were performed on the antenatal and postnatal 7th day of the cases, and UA and RA and RI, PI values were recorded.

UA Doppler Measurements

A Doppler US study was performed with LOGIQ E10 transabdominal pulsed 3.5-5 MHz transducers. Patients were scanned in the supine position for UA examination. The transducer was positioned medially at a modest inclination and longitudinally in the lower lateral quadrant of the abdomen. The location where the UA crossed the external iliac artery in the iliac fossa was determined, and the probe was placed 1 cm medial to the point of crossing. Then, pulsed Doppler flow forms were printed separately for both uterine arteries, obtained with an insonation angle of less than 30° and a sampling volume of 2 mm. The wall filter was set to 100 Hz. Three consecutive similar waveforms were obtained, and mean PI and RI were calculated for the uterine arteries on the left and right.

RA Doppler Measurements

RA Doppler measurements were performed with the same device and a 3.5 MHz convex transducer. Renal Doppler measurements were performed transabdominally while the pregnant woman was in the supine position. During the paused breathing period, the insonation angle was below 30 degrees, and the wall filter was 100 Hz. First, interlobar vessels in the renal pelvis were identified with color Doppler. Then, Doppler flow waveforms were obtained from the interlobar arteries in both kidneys for the highest Doppler frequency shift. The software on the US device was used to measure the RI and PI values.

Pulsed Doppler waveforms from the interlobar arteries in three distinct areas of the upper, middle, and lower third of the kidney were used to quantify maternal renal RI and PI.

At least three consecutive Doppler waveforms with comparable appearances were used to estimate RI and PI. Lastly, the average RI and PI values for the left and right kidneys were determined and noted. No significant difference was found in RI and PI between the right and left kidneys for each patient ($P > 0.05$).

Statistical Analysis

The Statistical Package Program for Social Sciences 11.5 (SPSS Inc., Chicago, IL) was used for statistical analysis. The independent t-test was used to compare quantitative data the chi-square test to evaluate qualitative data, along with descriptive statistical techniques (mean, standard deviation, and median) in the data review process.

Prenatal and postnatal changes in uterine and RA Doppler parameters were examined using the paired t-test, and the association between Doppler parameters and 24-hour urine proteinuria, was assessed using Spearman correlation analysis.

A 95% confidence interval was used to evaluate the results, and $P < 0.05$ was considered significant.

RESULTS

The demographic data of a total of 60 patients, 30 of whom were diagnosed with PE and 30 healthy pregnant women (who did not develop PE), as Table 1 provides a summary of the control group.

Six of the preeclamptic pregnant women showed severe PE, and the remaining 24 showed mild PE. The two groups did not differ significantly statistically in terms of body mass index, abortion, parity, age, or gravida.

Table 2 summarizes the clinical and laboratory information of preeclamptic pregnant women and healthy pregnant women. The mean proteinuria level in the PE group was 1363 mg/dL, while it was calculated as 173 mg/dL in the control group. The difference was statistically significant ($P < 0.05$).

The PE group had statistically significantly higher systolic and diastolic blood pressure compared to the control group ($P < 0.001$). Hemoglobin, platelet, alanine aminotransferase, aspartate aminotransferase, creatinine, and blood urea nitrogen values of patients in both groups were found to be within normal limits, and no statistically significant difference was observed between the groups in terms of blood values. There was a statistically significant difference between the two groups in terms of gestational age at delivery; the median value was 35 weeks in the PE group and 37 weeks in the control group ($P < 0.01$).

Tables 3 and 4 provide an overview of the antenatal and postnatal uterine and renal Doppler parameters for the PE and control groups.

Among the groups, only the right UA antenatal PI and RI values and postnatal PI value were found to be statistically significantly higher in the PE group in terms of both uterine and RA Doppler PI and RI values compared to the control group ($P < 0.05$).

Comparisons of antenatal and postnatal Doppler parameters of the PE group are summarized in Table 5 and those of the control group are summarized in Table 6. When the postpartum change in UA PI and R1 mean values was examined, no significant change was found in either group. The postpartum decrease in the mean value of right RA Doppler PI was significantly higher in the PE group. This decrease was statistically significant ($P < 0.05$). No statistically significant change was detected in the mean values of RA antenatal and postnatal Doppler PI and RI in all groups ($P > 0.05$). When investigating the association between uterine and RA Doppler values and protein content, right UA PI and RI values and 24-hour urine protein amount were found to be significantly correlated. No relationship was found between RA PI and RI values and 24-hour urine protein amount.

DISCUSSION

In the present study, we found a statistically significant relationship between UA Doppler parameters and the amount of proteinuria in PE cases. Although the right RA antenatal PI value was found to be higher compared to postnatal, no significant relationship was found between RA Doppler parameters and proteinuria. We thought that the small number of cases, or the fact that the Doppler examination was performed as early as the 7th postnatal day, had a negative effect on our results. Three to five percent of pregnant women develop PE, a pregnancy-specific illness marked by proteinuria and hypertension that develops after the twentieth week of pregnancy. In low- and middle-income countries, 10-15% of maternal deaths are directly related to PE and eclampsia.[13]

The early diastolic notch in the UA waveform is usually observed at the 14th week of normal pregnancy, but disappears after the 24th week.[10,11,14] In most studies, it is reported that the RI or

Table 1. Demographic Data of Patients

Demographic characteristics	Preeclampsia group (n=30)	Control group (n=30)	*P*
Age	32.43 ± 7.10	30.50 ± 714	0.29
Gravida	2 (1-5)	2 (1-8)	0.26
Parity	1 (0-4)	1 (0-3)	0.56
Abortion	0 (0-3)	0 (0-4)	0.20
BMI (kg/m^2)	27.69 ± 3.01	26.76 ± 2.51	0.20

Age and BMI (body mass index) are given as mean values, and gravida, parity, and abortion data are given as median values.

Table 2. Clinical and Laboratory Data of Preeclamptic and Normal Pregnant Women

Clinical and laboratory data	Preeclampsia group (n=30)	Control group (n=30)	*P*
Proteinuria (mg/24 h)	1363.23 ± 1636.88	173.53 ± 64.38	**0.00**
Systolic blood pressure (mmHg)	153.70 ± 11.28	104.17 ± 10.99	**0.00**
Diastolic blood pressure (mmHg)	98.17 ± 9.51	63.17 ± 7.71	**0.00**
Hemoglobin (g/dL)	12.08 ± 1.38	12,12 ± 1.28	0.90
Platelet (10^3/mL)	217.23 ± 83.61	209.90 ± 46.96	0.67
ALT (U/L)	13.80 ± 8.91	13.53 ± 10.10	0.91
AST (U/L)	21.30 ± 6.86	20.33 ± 8.29	0.62
Creatine (mg/dL)	0.59 ± 0.16	0.49 ± 0.10	0.13
BUN (mg/dL)	1l.57 ± 5.15	8.30 ± 4.18	0.09
Week of pregnancy at time of birth	35 (25-39)	37 (26-40)	**0.01**

Note: The amount of proteinuria, systolic blood pressure, diastolic blood pressure, hemoglobin, platelets, ALT, AST, creatinine, BUN, gestational week at the time of delivery, and gestational week at which ultrasound evaluation was performed are given as mean values.
ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen.

systolic/diastolic ratio is more valuable than PI in predicting PE in the mid trimester.[11,14,15] There were no differences in RA Doppler indices between normotensive and hypertensive pregnant women, even though pregnancy-induced hypertension (PPIH) is linked to elevated maternal systemic vascular resistance and luminal narrowing of renal glomerular arterioles.[12,16] Liberati et al.[17] investigated whether there were differences in interlobar RA PI and RI between normal and hypertensive pregnant patients. The measurements were similar in both groups. It was found that mild and moderate PE did not cause changes in the flow velocities and waveforms in the kidney and the interlobar artery.[17]

Similarly, no statistically significant difference between the groups was seen in the renal interlobar artery PI and RI values in our investigation. However, we found that right UA Doppler values in the antenatal period were noticeably higher in the preeclamptic women compared to the healthy control group. Unfortunately, this relationship could not be demonstrated in left UA Doppler parameters. Numerous investigations have documented postpartum UA impedance in patients with persistent hypertension and PE.[12,18,19] Maged et al.[19] evaluated uterine arterial resistance in preeclamptic and healthy women before and after delivery. Both pre- and postpartum measurements of UA PI and RI Doppler indices are significantly higher in women with PE compared with the control group. They claimed that either chronically elevated maternal vascular tone or insufficient trophoblastic invasion in the basal section of the decidua basalis and myometrium is the source of the rise in UA impedance. When comparing the antenatal and postnatal UA PI and RI values in our investigation, we found no discernible differences. We believed that the modest number of instances in the current study was connected to this. Postpartum UA blood flow velocimetry in normal pregnancies and pregnancies complicated by severe PE was studied by Weintraub et al.[20] Although no difference was observed between normotensive patients and preeclamptic pregnant women in terms of postpartum Doppler velocimetry measurements, the preeclamptic group had considerably more unilateral and bilateral early diastolic notches. In our study,

Table 3. Comparison of Antenatal Uterine and Renal Artery Doppler Parameters of Preeclampsia and Control Groups

UA and RA Doppler parameters	Preeclampsia group (n=30)	Control group (n=30)	*P*
Right UA antenatal PI	1.29 ± 0.57	1.01 ± 0.43	**0.03**
Right UA antenatal RI	0.62 ± 0.13	0.54 ± 0.16	**0.03**
Left UA antenatal PI	1.19 ± 0.72	1.04 ± 0.44	0.32
Left UA antenatal RI	0.58 ± 0.19	0.56 ± 0.13	0.57
Right RA antenatal PI	1.03 ± 0.29	1.03 ± 0.24	0.91
Right RA antenatal RI	0.60 ± 0.08	0.60 ± 0.07	0.81
Left RA antenatal PI	1.00 ± 0.27	1.00 ± 0.19	0.93
Left RA antenatal RI	0.60 ± 0.10	0.58 ± 0.08	0.54

UA, uterine artery; RA, renal artery; PI, pulsatility index; RI, resistive index.

Table 4. Preeclampsia and Control Groups' Postnatal Uterine and Renal Artery Doppler Values are Compared

Preeclampsia group (n=30)	Preeclampsia group (n=30)	Control group (n=30)	*P*
Right UA postnatal PI	1.32 ± 0.56	1.07 ± 0.32	**0.04**
Right UA postnatal RI	0.63 ± 0.13	0.59 ± 0.10	0.10
Left UA postnatal PI	1.22 ± 0.48	1.10 ± 0.47	0.36
Left UA postnatal RI	0.63 ± 0.11	0.57 ± 0.13	0.07
Right RA postnatal PI	0.92 ± 0.18	1.02 ± 0.26	0.08
Right RA postnatal RI	0.60 ± 0.06	0.60 ± 0.07	0.83
Left RA postnatal PI	0.92 ± 0.19	0.96 ± 0.19	0.37
Left RA postnatal RI	0.59 ± 0.09	0.58 ± 0.07	0.83

UA, uterine artery; RA, renal artery; PI, pulsatility index; RI, resistive index.

although no observation was made regarding notching in the UA, we encountered higher UA Doppler antenatal and postnatal PI RI values on the right side in the preeclamptic group.

When comparing antenatal and postnatal RA Doppler values, we found that the PI value of the right RA in the preeclamptic women decreased significantly in postnatal measurements. Pregnant hypertension patients often have decreased renal blood flow, as indicated by endogenous creatinine clearance tests. Histopathological alterations in renal microcirculation are linked to impaired renal function. It is debatable whether anomalies in renal arterial blood flow velocity waveforms indicate alterations in renal pathophysiology.[21] Zimmermann and Ranta et al.[11] examined the relationship between PI and RI values in maternal UA and intrarenal arteries as markers of vascular resistance in pregnant women at low and high risk of developing PPIH. In the study, no correlation was found between the RI values of both uterine arteries and the RI value of the right interlobar RA. There was no association between a persistent diastolic notch in the uterine arteries and intrarenal RI values. The intrarenal RI value was not different in patients who developed proteinuria and severe PPIH in later pregnancy compared with normal pregnant women. In another study, Bahser et al.[22] compared the resistance index in the intralobular RA in preeclamptic and healthy pregnant women. Pregnant women with PE were found to have a statistically higher resistance index than normal pregnant women. It was shown that the PI value was related to the amount of proteinuria, and the RI was related to the systolic blood pressure. Intrarenal Doppler indices are an important indicator of PE and provide the opportunity to predict nephropathy. Intrarenal Doppler indices suggested that they may be a prognostic tool for cardiovascular complications in patients with PE.[22]

Table 5. Antenatal and Postnatal Comparison of Uterine and Renal Artery Doppler Parameters in the Preeclampsia Group

Preeclampsia	Antenatal	Postnatal	*P*
Right UA PI	1.29 ± 0.57	1.32 ± 0.56	0.76
Right UA RI	0.62 ± 0.13	0.63 ± 0.13	0.64
Left UA PI	1.19 ± 0.72	1.22 ± 0.48	0.84
Left UA RI	0.58 ± 0.19	0.63 ± 0.11	0.10
Right RA PI	1.03 ± 0.29	0.92 ± 0.18	**0.01**
Right RA RI	0.60 ± 0.08	0.60 ± 0.06	0.42
Left RA PI	1.00 ± 0.27	0.92 ± 0.19	0.11
Left RA RI	0.60 ± 0.10	0.58 ± 0.07	0.63

UA, uterine artery; RA, renal artery; PI, pulsatility index; RI, resistive index.

Table 6. Antenatal and Postnatal Comparison of UA and RA Doppler Parameters in the Control Group

Control group	Antenatal	Postnatal	*P*
Right UA PI	1.01 ± 0.43	1.07 ± 0.32	0.32
Right UA RI			
Left UA PI			
Left UA RI			
Right RA PI			
Right RA RI			
Left RA PI			
Left RA RI			
Right UA PI	0.54 ± 0.16	0.59 ± 0.10	0.09
Right UA RI			
Left UA PI			
Left UA RI			
Right RA PI			
Right RA RI			
Left RA PI			
Left RA RI			
Right UA PI	1.04 ± 0.44	1.10 ±0.47	0.49
Right UA PI	0.56 ± 0.13	0.57 ±0.13	0.53
Right UA PI	1.03 ± 0.24	1.02 ±0.26	0.75
Right UA PI	0.60 ± 0.07	0.60 ± 0.07	0.92
Right UA PI	1.00 ± 0.19	0.96 ± 0.19	0.32
Right UA PI	0.58 ± 0.08	0.58 ± 0.07	0.71

UA, uterine artery; RA, renal artery; PI, pulsatility index; RI, resistive index.

Albuminuria and a lower GFR rate are indicators of renal glomerular injury and renal vasospasm, which are thought to cause impaired renal function secondarily in PE.[23-27] Kublickas et al.[28] looked into how maternal RA Doppler indices were affected by hypertension and illness, as well as by a typical pregnancy. Pregnant women with PE had lower renal blood flow velocity indices than those of women in a healthy pregnancy which suggests that PE is associated with greater reno-vascular resistance.

When we looked at the relationship between UA Doppler values and proteinuria, we discovered a connection between proteinuria and the PI and RI of the right UA. We found no significant correlation between RA Doppler parameters and proteinuria, which was unexpected. We thought that this was related to the small number of PE cases. RA waveforms were obtained by Gudmundsson and Marsâl[28] in non-pregnant, healthy pregnant, and preeclamptic women. In preeclamptic women, RA waveforms were shown to be unrelated to mean arterial pressure and the severity of proteinuria. The placenta's impaired growth results in increased blood flow resistance in the uteroplacental circulation. Impaired development of the placenta means constantly increasing resistance to blood flow in the uteroplacental circulation. Inadequate trophoblastic invasion is thought to be a contributing factor in placental diseases, while the precise process remains unknown.[29] van Asselt et al.[29] assessed whether maternal blood pressure, proteinuria, and placental vascular resistance were correlated, and whether Doppler velocity assessment of placental circulation could predict unfavorable outcomes of pregnancies affected by PE. Abnormalities on both sides of the placenta were associated with adverse pregnancy outcomes. Negative pregnancy outcomes were found to be more prevalent in the

groups with increased vascular resistance on both sides of the placenta than in the groups with increased vascular resistance on just one side. They found significant relationship between proteinuria and UA PI value, but There was no relationship between mean maternal arterial pressure and UA PI.[29,30] Antihypertensive medications that reduce blood pressure without changing placental vascular resistance or the extent of protein leakage into the urine are administered to some patients with more severe PE. This may conceal a potential link between maternal blood pressure and UA vascular resistance.[30]

Study Limitations

The small number of patients in our study is one of its drawbacks; thus, it is possible that the data collected will change when the number of patients taking part in the study rises.

The UA's notch was also investigated in several relevant studies; however, our study did not examine any changes that might be connected to this parameter. Postnatal Doppler parameters include values determined within one week postpartum. Performing postnatal ultrasonography evaluation at a longer interval may yield different results.

In our study, we found UA Doppler parameters to be associated with both PE and proteinuria. In our study, no significant relationship was found between renal Doppler parameters (renal PI, RI) and proteinuria in preeclamptic pregnant women. Studies examining the connection between RA Doppler and PE have produced contradictory findings. As a result, this field requires additional prospective research with a large number of cases.

Ethics

Ethics Committee Approval: It is a prospective study conducted by the Karadeniz Technical University Faculty of Medicine Scientific Research Ethics Committee with the approval of the ethics committee with protocol number 2020/35 on 28.01.2020.

Informed Consent: Written consent is obtained from every patient admitted to the hospital after they read and sign the informed consent form.

Footnotes

Author Contributions

Concept – M.E.A., G.D.; Design – M.E.A., G.D.; Data Collection or Processing – M.E.A.; Analysis or Interpretation – M.E.A., G.D.; Literature Review – M.E.A.; Writing, Reviewing and Editing – M.E.A., G.D.

Declaration of Interests: The authors declare no conflict of interest regarding the publication of this paper.

Funding: The authors declare no financial support or funding.

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