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Comparison of Oxidative and Antioxidative Parameters in The Exudative and Transudative Pleural Effusion

Eksuda ve Transuda Vasfındaki Plevral Sıvılarda Oksidatif ve Antioksidatif Parametrelerin Karşılaştırılması

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Abstract

Background: The initial step in diagnosing pleural effusion is to distinguish between transudate and exudate. In establishing this distinction, numerous parameters, particularly the Light criteria, have been utilized; however, there are instances where inaccurate results may arise. This study examined oxidative stress markers that may contribute in distinguishing between exudate and transudate fluids.

Materials and Methods: This study included 50 patients diagnosed with pleural effusion and 30 healthy individuals. The Total Oxidative Status (TOS) and Total Antioxidant Capacity (TAC) parameters were analyzed in pleural fluid and serum samples using the Erel technique on an Abbott Aeroset autoanalyzer in the biochemistry laboratory.

Results: The fluid TOS and TAC values in patients with the exudate group were higher than those in the transudate group ($p<0.005$). The exudate and transudate group exhibited elevated serum TOS levels in comparison to the control group ($p<0.005$). The serum TAC level in the control group was higher compared to the transudate and exudate groups. The serum (OSI) values in patients with exudative and transudative effusions were elevated compared to those in the control group. Serum OSI levels were significantly higher in exudative patients compared to both transudative patients and the control group ($p <0.001$).

Conclusions: Oxidative marker levels are significantly increased in exudative pleural effusions. In differentiating pleural fluid exudate from transudate, we determined that assessing the levels of TOS and TAC, utilized as oxidative stress indicators, may aid in diagnosis.

Keywords: Transudate, exudate, total oxidative status, total antioxidant capacity, oksidative stress index.

ÖZ

Amaç: Plevral efüzyonlarda, sıvının transuda eksuda ayrımının yapılması tanının ilk basamağını oluşturur. Bu noktada Light kriterleri başta olmak üzere pek çok parametre kullanılmıştır ancak bazen yanlış sonuçlar elde edilebilmektedir. Bu çalışmada sıvının transuda ve eksuda ayrımına katkı sunacağını düşündüğümüz oksidatif stres markırlarını araştırdık.

Gereç ve Yöntem: Çalışmaya plevral efüzyon tanılı 50 hasta ve 30 sağlıklı erişkin alındı. Biyokimya laboratuarında serum ve plevral sıvı örneklerinde, Abbot Aeroset marka oto analizör cihazında Erel metoduyla Total Oksidatif Seviye (TOS) ve Total Antioksidan Kapasite (TAK) parametrelerinin düzeyleri incelendi.

Bulgular: Eksuda vasıflı sıvısı olan hastalardaki sıvı TOS ve TAK değerleri, transudatif grubunun sıvı TOS ve TAK düzeylerine kıyasla daha yüksek idi ($p<0.005$). Eksuda ve transuda grubunun serum TOS düzeyleri, kontrol grubunun serum TOS düzeyine kıyasla daha yüksek idi ($p<0.005$). Kontrol grubunun serum TAK düzeyi, eksuda ve transuda grubunun serum TAK düzeylerine kıyasla daha yüksek idi. Eksudatif ve transudatif sıvılı hastaların serum OSI düzeyleri, kontrol grubunun serum OSİ düzeyine kıyasla daha yüksek idi. İstatistiksel olarak eksudalı hastalarda serum OSİ düzeyi, transudatif grup ve kontrol grubuna gore anlamlı oranda yuksek bulundu ($p <0,001$).

Sonuç: Eksuda vasıflı efüzyonlarda, oksidatif markır düzeylerinin artışının daha fazla olduğu görülmektedir. Oksidatif stres belirteci olarak kullanılan TOS ve TAK düzeyi ölçümünün plevral sıvı eksuda transüda ayrımında, tanıya katkı sunabileceği sonucuna vardık.

Anahtar kelimeler: Transuda, eksuda, Total oksidatif seviye, total antioksidan kapasite, oksidatif stres indeksi

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Highlights

- Pleural fluid TOS and TAC levels are higher in exudative than transudative effusions, while serum TAC is highest in the control group compared to both effusion types.
- Serum TOS and OSI are higher in effusion groups, highest in exudates.
- Combined TOS, TAC, and OSI may aid in exudate–transudate differentiation.

Introduction

Pleural effusion is characterized by an abnormal accumulation of fluid in the pleural space and occurs due to an imbalance between the production and absorption of pleural fluid (1,2). Differentiating between exudative and transudative effusions is crucial, as the underlying mechanisms and subsequent treatment modifications rely on this distinction (3). To classify effusions as transudative or exudative, Lights criteria are most commonly utilized. Pleural effusions commonly result from increased hydrostatic pressure or decreased plasma colloid-osmotic pressure. Exudative effusions are typically associated with changes in pleural surface permeability resulting from inflammation, malignancy, or insufficient lymphatic drainage (4,5).

Normal metabolic processes in the body generate free radicals as a byproduct of oxygen utilization. Reactive oxygen derivatives can be detrimental to the organism if not converted to an inactive form or if produced in excessive amounts that exceed the body's defense mechanisms (6). Lipid peroxidation induced by reactive oxygen species can result in cell membrane dysfunction, diminished activity of membrane-bound receptors and enzymes, and heightened membrane permeability. The effects may significantly impact the development of various diseases. This condition is termed "Oxidative Stress," with the consequent harm identified as oxidative damage.

The body has antioxidant defense mechanisms that defend against the detrimental effects of reactive oxygen species. Antioxidants are classified into two primary categories: natural (endogenous) and exogenous antioxidants, as well as enzymatic and non-enzymatic antioxidants. Enzymatic antioxidants include mitochondrial cytochrome oxidase, superoxide dismutase (SOD), catalase, glutathione peroxidase (GSH-Px), glutathione transferase, prolidase and hydroperoxidase (7,8).

While non-enzymatic antioxidants are lipid-soluble α-tocopherol (vitamin E), β-carotene, and water-soluble ascorbic acid (vitamin C), along with melatonin, cysteine, ceruloplasmin, hemoglobin, and bilirubin (9). Exudative effusions are expected to exhibit significantly elevated oxidant levels and reduced antioxidant levels in comparison to transudative effusions. The objective of this study was to evaluate the variations in oxidant and antioxidant parameters in pleural fluid and serum, as well as to analyze the potential of TAC, TOS, and OSI as markers for differentiating between exudative and transudative pleural effusion.

Material and Methods

Study design

This prospective, single-center study was conducted at the Pulmonary Diseases Clinic at Harran University Hospital between January 2009 and July 2009. It included 50 patients with pleural effusion and 30 healthy individuals who formed the control group.

Pleural effusion was diagnosed through a thorough methodology that included physical examination, posteroanterior and left chest radiography, and, in certain instances, ultrasound imaging. Pleural fluid samples and peripheral venous blood specimens were collected from all patients diagnosed with pleural effusion. A volume of 40 mL of fluid was collected into a tube via the thoracentesis procedure. Peripheral venous blood samples were taken and kept in serum collection tubes. The biochemistry laboratory analyzed glucose, lactate dehydrogenase (LDH), total protein, albumin, cholesterol, and total bilirubin levels in pleural fluid and blood samples. Pleural fluid samples experienced cell count, gram staining, and non-specific culture analysis. The analysis of acid-fast bacilli (AFB) present staining the fluid using the Ziehl-Neelsen method and inoculating it onto Lowenstein-Jensen medium. The fluids were classified as exudates and transudates based on Light's criteria (8). The parameters referred to as "light criteria" are as follows (10):

a. Pleural protein to serum protein ratio (protein ratio) ≥ 0.5

b. Pleural LDH to serum LDH (LDH ratio) ≥ 0.6

c. Pleural LDH >200 U/lt or Pleural LDH >2/3 of the upper limit of the serum LDH

Fluids were classified as exudate if at least one of Light's criteria was met, and as transudate if none were met (10).

Alongside Light's criteria, particularly in pleural effusions linked to congestive heart failure (CHF), the albumin gradient has been employed for transudate-exudate differentiation. (Albumin gradient: If serum albumin - pleural fluid albumin <1.2, it is classified as an exudate) (12).
The albumin gradient, particularly in instances involving diuretic use, has been shown to aid in the precise classification of pleural effusion (13).
This study classified patients based on their etiological diagnoses. Patients with exudative effusion caused tuberculosis, malignancy, parapneumonia, pericarditis, rheumatoid arthritis, hydatid cyst, or pulmonary embolism. In contrast, transudative effusion was due to congestive heart failure, liver cirrhosis, chronic kidney failure, or pulmonary embolism.
A 5-microliter sample was taken from the collected pleural fluid and blood samples to assess Total Oxidative Status (TOS), Total Antioxidant Capacity (TAC), and Oxidative Stress Index (OSI). Pleural fluid and blood samples were left at room temperature for 30-60 minutes before centrifugation at 3000-5000 × g for 10-15 minutes. Subsequently, serum and pleural fluid were separated using an automatic pipette. The samples were stored at -80 °C for the assessment of TOS, TAC, and Oxidative Stress Index (OSI). Upon obtaining a sufficient number of samples, the sera and fluids were thawed and analyzed in the biochemistry laboratory utilizing an Abbot Aeroset autoanalyzer with the Erel method to assess TOS and TAC parameters (14,15).
The OSI value for each participant was calculated by proportionally relating TOS to TAC (16).

Statistical analysis

IBM (International Business Machines) SPSS 11.0 (SPSS Inc. Chicago USA) program was used for statistical analysis. The study data was evaluated using descriptive statistical methods, including the mean and standard deviation. In addition, Student's t-test and One-Way ANOVA were used to compare quantitative data between different groups. These statistical tests were only applied to parameters that indicated a normal distribution. Receiver Operating Characteristics (ROC) analysis was performed to assess the diagnostic efficacy of TAC and Oxidative Stress Index (OSI) levels in differentiating exudative and transudative pleural effusions. The Light criteria have been used to determine the cutoff points for differentiating between transudative and exudative pleural effusions. The results were assessed using a 95% confidence interval, with a significance level of $p < 0.05$.

Ethical Approval

The study was approved by the Ethics Committee of Harran University Faculty of Medicine (number: HRU/19.06.10, date: 19.06.2009). Informed consent was obtained from all patients. All procedures were carried out in accordance with the Declaration of Helsinki.

Results

The study involved 50 patients with pleural effusion. Patients were categorized into two groups based on the Light criteria: the exudative pleural effusion group, comprising 30 patients (60.00%), and the transudative pleural effusion group, comprising 20 patients (40.00%). The exudate group consisted of 15 (50.00%) malignancies, 3 (10.00%) cases of parapneumonia, 6 (20.00%) cases of tuberculosis, 2 (6.67%) cases of pericardial disease, 2 (6.67%) cases of pulmonary embolism, 1 (3.33%) case of rheumatoid arthritis, and 1(3.33%) case of hydatid cyst. The group of transudates included 16 (80.00%) cases of congestive heart failure, 1 (5.00%) case of chronic renal failure, 1 (5.00%) case of liver cirrhosis, and 2 (10.00%) cases of pulmonary embolism **(Table 1).**

Table 1. Patient distribution based on diagnoses.

Parameters	**n, (%)**	**Parameters**	**n, (%)**
Exudate	30(60)	**Transudate**	20(40)
Malignancies	15(26)	Congestive Heart Failure	16(32)
Tuberculosis	6(12)	Chronic Renal Failure	1(2)
Parapneumonia	3(6)	Liver Cirrhosis	1(2)
Pulmonary Embolism	2(4)	Pulmonary Embolism	2(4)
Others*	4(8)		

Abbreviations: * One patient with rheumatoid arthritis, one with a hydatid cyst, and two with pericardial disease.

Evaluation of the demographic data revealed no statistically significant difference in mean age among the exudate, transudate, and control groups (p>0.05) **(Table 2)**. Male patients were more prevalent in the group with exudative pleural effusion, compared to patients with transudative pleural effusions and the control group. However, there was no significant difference between groups for sex distribution (p> 0,05) **(Table 2).** There was no significant difference in smoking status between the exudate, transudate and the control group (p> 0,05) (**Table 2)**.

Table 2. Demographic data of patients

Variables	Exudate (n=30)	Transudate (n=20)	Control (n=30)	P
Gender, (M/F)	22 / 8	10 / 10	18 / 12	> 0.05
Age, (Years)	54.0 ± 14.07	56.80 ± 15.97	52.17 ± 9.91	> 0.05
Weight (kg)	69.07 ± 7.99	66.10 ± 7.88	70.07 ± 7.93	> 0.05
Smoking, (Yes/No)	17 / 13	9 / 11	14 / 16	> 0.05

When the LDH level of pleural fluid is set at an upper limit of 200 IU based on Light's criteria, it was found that the LDH values of 2 cases with transudative fluid had levels higher than 200. Furthermore, when the cut-off value for the pleural fluid/serum LDH ratio was set as 0.6, it was found that all cases classified as transudative had values below this value **(Table 3)**. When the cut-off value for the ratio of pleural fluid to serum total protein is set at 0.5, it was found that all cases classified as exudate had values higher than this threshold. In contrast, all cases classified as transudate had values lower than this threshold **(Table 3)**.

Table 3. Diagnostic value of Light's criteria in differentiating the transudate and exudate.

Variables	PE LDH >200	PE LDH <200	PE / Serum LDH >0,6	PE / Serum LDH <0,6	PE / Serum Protein >0,5	PE / Serum Protein <0,5
Exsudat	30	-	30	-	30	-
Transudate	2	18	-	20	-	20

Abbreviations: LDH: Lactate dehydrogenase

In the study group, the serum TOS levels of patients with exudative and transudative effusions were compared to those of the control group. The results revealed that both exudative and transudative patients had higher serum TOS levels than the control group. (p<0,001) **(Table 4, Figure 1A)**. Additionally, serumTOS levels were significantly higher in the exudative patient group compared to the transudative group. (p<0,001) **(Table 4, Figure 1A)**.

Table 4. Comparison of TAC, TOS and OSI values in exudate, transudate and control serums.

Parameters	Exudate (n=30)	Transudate (n=20)	Control (n=30)	p
TAC (mmol Trolox Eqv:/L)	0.79 ± 0.14	0.92 ± 0.12 ^{a***}	1.02 ± 0.12b***, c***	<0.001
TOS (µmol H2O2 Eqv./L)	33.43 ± 14.15	21.20 ± 8.93 ^{a***}	19.55 ± 8.95 ^{b***}	<0.001
OSI (Arbitrary Unite)	4.18 ± 1.59	2.37 ± 1.15 ^{a***}	1.93 ± 0.89 ^{b***}	<0.001

Abbreviations: a: A significant difference exists between the exudative group and the transudative group. b: A significant difference exists between the exudative group and the control group. c: A significant difference exists between the transudative group and the control group. ***: p≤ 0,001, **: p≤0,01, *: p≤0.05

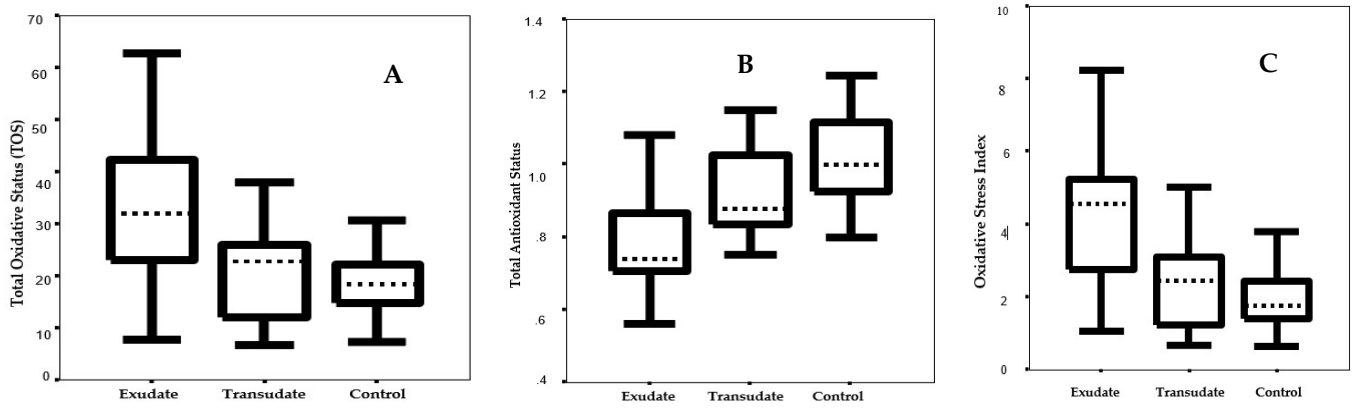

Figure 1. Comparison of TOS (A), TAC (B) and OSI (C) values in the distinction between exudate, transudate and control serums.

By comparing the levels of TAC in the blood samples from patients with exudative and transudative effusions to the control group, it was found that the TAC levels in the control group were higher than those in both the exudative and transudative patients **(Figure 1B)**. The exudate group had the lowest TAC levels (p <0,001) **(Figure 1B)**.
In the study group, the serum OSI levels of patients with exudative and transudative effusions were compared to those of the control group. The results revealed that both exudative and transudative patients had higher serum OSI levels than the control group **(Figure 1C**). Additionally, serum OSI levels were significantly higher in the exudative patient group compared to the transudative group and the control group (p <0,001).
By comparing the levels of TOS in the pleural fluid from the patients with exudate and transudate, it was found that the TOS levels in the exudative group was higher than the transudative group (p <0,001) **(Table 5).**
By comparing the levels of TAC in the pleural fluid from the patients with exudate and transudate, it was found that the TAC levels in the exudative group were higher than the transudative group (p <0,001) **(Table 5).**

Table 5. Comparison of fluid TAC, TOS and OSI values in the distinction between exudate and transudate.

Parameters	Exudate (n=30)	Transudate (n=20)	p
TAC (mmol Trolox Eqv:/L)	0.84±0.17	0.79±0.22	0.408
TOS (μmol H2O2 Eqv./L)	20.38±13.02	11.70±7.59	0.010
OSI (Arbitrary Unite)	2.43±1.39	1.64±1.14	0.040

By comparing the levels of OSI in the pleural fluid from the patients with exudate and transudate, it was found that the OSI levels in the exudative group was higher than the transudative group (p <0,001) **(Table 5).**
We utilized ROC (receiver operating characteristic) analysis to assess the diagnostic performance of TAC and OSI, which show significant differences between exudative and transudative pleural fluids, in characterizing the properties of pleural fluid. Additionally, we assessed the diagnostic utility of both parameters by contrasting their levels in pleural fluid with serum values, as well as their effectiveness in differentiating exudative from transudative pleural effusions utilizing Light's criteria. The area under the ROC curve for serum OSI value was roughly 0.817, for pleural fluid it was 0.690, and for P/S OSI value it was 0.498. Therefore, serum OSI levels had the greatest diagnostic value for exudative effusions, with a 95% confidence interval of 0.70-0.94.
ROC curve analysis demonstrated an area under the curve of 0.183 for serum OSI, 0.310 for pleural fluid OSI, and 0.502 for the pleural fluid-to-serum OSI ratio. Accordingly, the ratio of pleural fluid OSI values to serum OSI values had the highest diagnostic value for identifying transudative fluids, with a 95% confidence interval of 0.33-0.67. However, the OSI values were not statistically significant in the diagnosis of pleural fluids characterized as transudate.
In the analysis of the ROC curve, the area under the curve for serum TAC value was found to be approximately 0.213, for pleural fluid it was 0.590, and for the P/S TAC value it was 0.753. Accordingly, the ratio of pleural fluid TAC values to serum TAC values has the highest diagnostic value for identifying exudative fluids, with a 95% confidence interval of 0.60-0.90 **(Figure 2A).**
The ROC analysis results for the transudate values we obtained were significantly distinct from those of the exudates. In these patients, the area under the curve for serum TAC value was 0.787, for pleural fluid it was 0.410, and for P/S TAC value it was 0.247. According to this, the serum TAC values have the highest diagnostic value for identifying transudative fluids with a 95% confidence interval of 0.66-0.91 **(Figure 2B).**

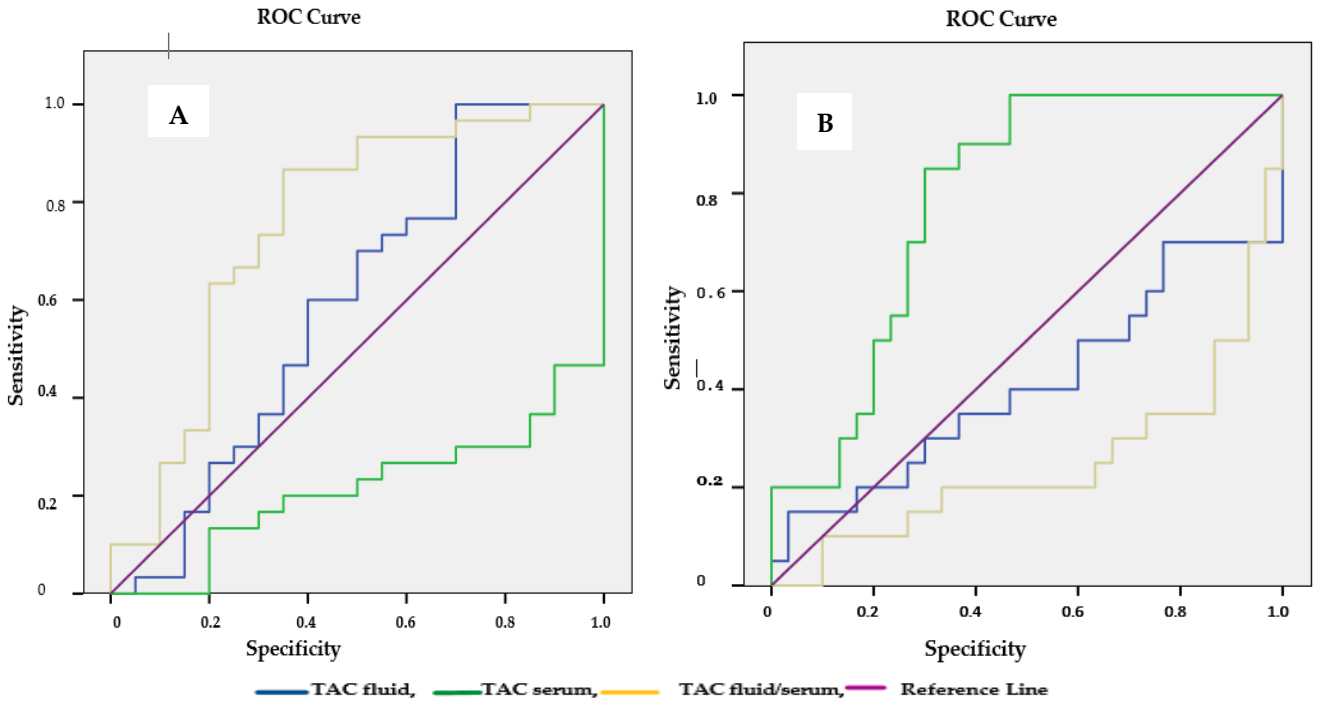

Figure 2. ROC analysis of TAC values in fluid and serum in patients with exudative (A) and transudate (B) fluid.

Discussion

Various parameters have been investigated to distinguish transudative from exudative pleural effusions, which may accumulate in the pleural space due to diverse etiologies. In 1972, Light et al. demonstrated that the differentiation of transudative from exudative pleural effusions could be enhanced using three parameters, which have since become known as Light's criteria (10). The current strategy for classifying pleural effusions is based on thıs criteria established by Light. In their analysis of 150 pleural effusions, all but one exudate had at least one of the three criteria, although only one transudate presented any of the three (10).

Burges et al. reported a sensitivity of 98% and a specificity of 83% in their study using Light's criteria for differentiating pleural effusions (17).

In the study conducted by Romeo and colleagues involving 297 patients with pleural effusion, when the fluids were classified as transudates or exudates based solely on the LDH parameter, the sensitivity was found to be 65.5%, specificity 100%, and accuracy 70.6% (18). In the present study, when fluids were categorized only by the LDH parameter, it was shown that the LDH levels in two transudate instances exceeded 200 U/L.

In their study utilising the P/S LDH ratio, Romero et al. misclassified 18.1% of transudates and 7.2% of exudates, yielding a sensitivity of 92.8%, specificity of 81.8%, and an accuracy of 91.1% (18). The present study indicated that when classified fluids based on the P/S LDH ratio, all transudate cases were below the 0.6 threshold, whereas all exudate cases above this limit.

Maranhao et al. investigated the significance of pleural LDH and total protein in differentiating between exudates and transudates, reporting sensitivities of 99.4% and 98.5%, and specificities of 72.6% and 83.4%, respectively (19). This study revealed that when fluids were categorized based on the P/S total protein ratio, all transudate cases were below the 0.5 cut-off value, whereas all exudate cases exceeded this threshold.

Heffner and colleagues conducted a meta-analysis involving 14,448 patients across 11 studies, yielding the following results for the Light criteria: P/S LDH ratio >0.6 demonstrates 88% sensitivity and 81.8% specificity; P/S total protein ratio >0.5 exhibits 89.5% sensitivity and 90.9% specificity; and pleural LDH > 2/3 of the upper limit of serum LDH shows 91.4% sensitivity and 85% specificity (20).

In recent years, additional parameters have been proposed for more reliably distinguishing transudates from exudates than Light's criteria, such as pleural fluid cholesterol level, pleural fluid to serum cholesterol ratio, alkaline phosphatase value, pleural fluid to serum cholinesterase ratio, and pleural fluid to serum bilirubin concentration ratio (21,22). However, all these alternative parameters still misclassified certain effusions, rendering their superiority over Light's criteria insignificant. Misclassifications predominantly occur in patients with congestive heart failure who are administered diuretics. In those with pleural effusion due to congestive heart failure, the albumin gradient is utilized

to distinguish between transudate and exudate (22). In this study, while no patients were undiagnosed based on total protein levels, the albumin gradients in all exudative cases were <1.2 g/dl. Two transudative cases with a fluid LDH level exceeding 200 U/L were correctly classified utilizing the albumin gradient. Both instances included patients utilizing diuretics for congestive heart failure (CHF).

Papageorgiou et al. assessed oxidative stress levels in pleural effusion fluid to differentiate between exudative and transudative effusions. Their studies revealed that oxidative stress levels were higher in exudative fluids compared to transudative fluids, and they reported that the correct diagnosis was established for 106 patients who had been misclassified according to the Light criteria utilizing their newly proposed marker. They stated that with this marker, a very high proportion of correct diagnosis was reached in the distinction of exudative and transudative pleural fluids, with 96.8% sensitivity and 96.3% specificity (22).

Erdoğan and colleagues concluded that longer stays in the intensive care unit and extended mechanical ventilation were associated with a significant decrease in serum total antioxidant levels, alongside significant increases in total oxidant levels, oxidative stress index, and prolidase levels (7).

Hammouda et al. studied malondialdehyde (MDA), a marker of free oxygen radical activity, in distinguishing between transudative and exudative pleural fluids, and found that the levels of MDA were higher in exudative pleural fluids compared to transudative fluids (23). Yadav et al. studied the levels of malondialdehyde (MDA), C-reactive protein (CRP), and uric acid in pleural fluid, compared the levels in exudative and transudative pleural fluid. MDA and CRP levels were significantly higher in the pleural fluid of the exudative type compared to the transudative type (24). These two studies shown that oxidative stress is more severe in exudates compared to transudates, probably because of the increased production of reactive oxygen species, which could serve as markers for distinguishing between exudates and transudates.

This study, similar to the previously stated studies, revealed that TOS levels were significantly higher in exudative pleural fluids in comparison to transudative fluids. Furthermore, it has been established that the TOS and OSI values in the serum of patients exhibiting exudative fluid characteristics are higher compared to the serum levels of patients with transudative fluid. The serum OSI values in patients with exudative fluid demonstrated significant diagnostic value, exhibiting a 95% confidence interval for exudate diagnosis.

In the study by Aydınoğlu et al. involving patients with parapneumonic pleural effusion, the blood TAC level in the control group was significantly higher than that in the exudate and transudate groups, with statistical significance observed (25). Liu et al. found increased DNA oxidative damage in the lymphocytes of cancer patients presenting malignant pleural effusion, alongside reduced TAC levels in their plasma (26). In our study group, the TAC values of patients with exudative fluid were lower than those of the transudative fluid group and the healthy control group. This circumstance may facilitate the identification of elevated OSI values in patients with exudative fluid.

This study analyzed the ratio of pleural fluid TAC levels to serum TAC levels. Based on the individual reflections of both parameters and their ratio, our ROC curve analysis established that it is a 95% reliable indicate for differentiating exudate from transudate in pleural fluid based on their ratio. The statistically significant ratio of antioxidants in pleural fluid compared to serum, along with the diagnostic utility in distinguishing exudative pleuritis from transudative pleuritis, suggests the possible incorporation of a new parameter in this domain. Nevertheless, this outcome requires validation through more comprehensive studies. In another study by Yadav et al, elevated levels of MDA and CRP were observed in the exudative fluid, indicating a direct correlation with the localized production of reactive oxygen species in the pleural exudate (24).

These results indicate that the increased level of inflammation in the pleura is mirrored by inflammatory markers in both the pleura and serum. The present study's findings indicate that oxidative stress levels are elevated in cases with exudative fluid. This spike may be ascribed to both the heightened inflammation in the fluid and the elevated serum oxidant levels in exudate-associated disorders comparative to other diseases.

Study limitations

The study has some limitations. The limited sample size (50 patients and 30 controls) and the single-center design might restrict the generalizability of the findings. Measurements obtained only using the Erel technique necessitate validation through alternative methods. In addition, there is an absence of follow-up data to investigate the long-term associations between clinical parameters and oxidative markers.

Conclusion

At the distinction between exudate and transudate the occasional insufficiency of Light's criteria necessitates the exploration of novel diagnostic approaches. This study revealed a notable elevation in TOS and OSI, markers of oxidative stress, in exudative fluids. The increased ratio of pleural fluid TAC levels to blood TAC levels observed among exudative patients was notably significant. These parameters may be used as an effective diagnostic instrument for differentiating exudate from transudate.

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