ORIGINAL ARTICLE

The effect of superoxide dismutase on lipid peroxidation products and antioxidant activity in peritoneal exudate in the terminal phase of peritonitis

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ABSTRACT

Background and aim: Peritonitis is a common and clinically significant disease of the abdominal cavity. In the terminal stage of the disease, increased oxidative stress leads to the intensification of lipid peroxidation processes and impairment of the antioxidant defense system. The aim of this study was to evaluate the levels of lipid peroxidation products in peritoneal exudate obtained from patients with terminal peritonitis and to investigate the effect of superoxide dismutase (SOD) on these parameters under ex vivo conditions.

Methods: The study included 30 patients (17 males and 13 females; age range 34–72 years) diagnosed with terminal peritonitis who received standard clinical management. Peritoneal exudate samples obtained during surgery were divided into aliquots under ex vivo conditions and incubated at 10°C for 6 and 24 hours with and without the addition of superoxide dismutase (SOD). Analyses were performed within each sample using a

Received: 4 April 2026 | Accepted: 4 May 2026

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paired design. Malondialdehyde (MDA), diene conjugates (DC), and total antioxidant activity (TAA) were measured in the peritoneal exudate.
Results: At baseline, MDA and DC levels were 2.98 ± 0.08 nmol/mL and 2.56 ± 0.14 nmol/mL, respectively, while total antioxidant activity was 21.09 ± 0.57. After 24 hours of incubation with SOD, MDA and DC levels significantly decreased, whereas total antioxidant activity significantly increased ($p < 0.001$).
Conclusions: These findings highlight the potential therapeutic relevance of antioxidant approaches aimed at reducing oxidative stress in peritonitis. (www.actabiomedica.it)

Key words: terminal peritonitis, peritoneal exudate, lipid peroxidation, superoxide dismutase, antioxidant activity, adjunctive therapy

Introduction

Peritonitis is one of the most common acute conditions affecting the abdominal cavity. Despite advances in medical management, severe peritonitis remains a significant clinical problem due to systemic inflammation and oxidative stress–related tissue damage (1-3). In the terminal stage, the accumulation of endotoxins and other toxic substances leads to profound metabolic disturbances, cellular membrane damage, and the development of conditions conducive to septic shock (4). A marked increase in lipid peroxidation (LPO) products and reactive oxygen species is observed at this stage (5-7). Oxidative stress plays a critical role in the progression of inflammatory and metabolic disorders by enhancing lipid peroxidation, damaging cellular membranes, and impairing antioxidant defense systems (8,9). Assessment of oxidative stress markers in peritoneal exudate may provide clinically relevant information regarding disease severity and progression (10,11). Lipid peroxidation products, particularly malondialdehyde (MDA) and diene conjugates (DC), contribute to cellular membrane damage and disruption of metabolic processes, thereby amplifying oxidative stress and promoting tissue injury (12,13). These processes lead to tissue hypoxia, impaired microcirculation, disseminated intravascular coagulation, and ultimately multiple organ failure (14,15). The imbalance between increased lipid peroxidation and impaired antioxidant defense mechanisms in peritonitis complicates the neutralization of free radicals (16,17). Therefore, antioxidant enzymes such as superoxide dismutase may play a crucial role in reducing the intensity of lipid peroxidation and enhancing antioxidant protection, potentially representing a therapeutic approach for modulating oxidative stress (18,19). Thus, the evaluation of lipid peroxidation products and antioxidant status in peritoneal exudate obtained during terminal peritonitis reflects the mechanisms of oxidative stress and endogenous intoxication, providing a rationale for investigating the modulatory effects of superoxide dismutase (20). However, despite substantial evidence of oxidative stress in peritonitis, the dynamics of lipid peroxidation in peritoneal exudate from patients with terminal peritonitis have not been sufficiently studied, particularly with regard to the ex vivo effects of superoxide dismutase (21). The aim of the present study was to evaluate oxidative stress markers in peritoneal exudate obtained from patients with terminal peritonitis and to assess the potential modulatory role of superoxide dismutase, with a focus on its clinical relevance. In this study, we investigated whether lipid peroxidation is significantly elevated in peritoneal exudate during terminal peritonitis and whether ex vivo administration of superoxide dismutase can attenuate oxidative damage and enhance antioxidant capacity (22). Understanding these mechanisms may have important clinical implications for the development of adjunctive therapeutic strategies targeting oxidative stress.

Materials and methods

This study was conducted at the Scientific Research Center of Azerbaijan Medical University. It examined changes in lipid peroxidation products in peritoneal exudate (PE) obtained from the abdominal cavity of 30 patients with terminal-stage peritonitis who had undergone surgery and received standard clinical treatment. Peritoneal exudate samples were collected under standardized conditions intraoperatively, immediately after opening the abdominal cavity and prior to any lavage or additional manipulation.

Sample handling

Samples were processed immediately after intraoperative collection under sterile conditions. All procedures were performed according to a standardized protocol to minimize pre-analytical variability. Samples exhibiting visible hemolysis or contamination were excluded from analysis. The study population included 30 patients (17 males and 13 females) aged 34–72 years.

Inclusion criteria

Patients diagnosed with advanced peritonitis who underwent emergency surgical intervention for clinical indications and provided informed consent were included in the study, and intraoperative peritoneal exudate samples were collected from patients with peritonitis of different etiologies.

Exclusion criteria

Patients with chronic liver or kidney disease, immunodeficiency, malignancy, gynecological disorders, or incomplete clinical records were excluded. The mean age of the patients was 52.3 ± 11.4 years, ensuring adequate representation of both sexes. Simultaneously, the effect of adding superoxide dismutase (SOD) to the peritoneal exudate on the dynamics of lipid peroxidation products was investigated. These experiments were performed in vitro, with samples incubated in a thermostat at 10°C for 6 and 24 hours. PE aliquots were processed and incubated under aseptic conditions; however, no protease inhibitor cocktail was added prior to incubation. Samples were maintained at 10°C to minimize enzymatic degradation and microbial proliferation during the incubation period. The peritoneal content was obtained from patients with the following etiologies:

1. Peritonitis secondary to gastric ulcer perforation – 6 patients
2. Peritonitis secondary to gallbladder perforation – 6 patients
3. Peritonitis associated with small bowel obstruction – 6 patients
4. Peritonitis secondary to appendiceal perforation – 6 patients
5. Postoperative peritonitis following genital organ surgery – 6 patients

Peritoneal contents were collected and prepared as follows: immediately after opening the abdominal cavity during laparotomy, the contents were aspirated using an electric suction device. Large particulate matter was removed, and the sample was filtered through a sterile filter into a glass container for subsequent analysis.

Definition of terminal peritonitis

In this study, terminal peritonitis was defined based on a combination of clinical and intraoperative criteria. These included signs of diffuse peritoneal inflammation, severe endotoxicosis or sepsis, hemodynamic instability, and evidence of multiple organ dysfunction. In all included patients, intraoperative findings were consistent with diffuse purulent-fibrinous peritonitis. When available, disease severity was additionally evaluated using clinical records.

Experimental groups and study design

Patients were selected using stratified enrolment to ensure homogeneity with respect to age, sex, and disease severity. Instead of assigning patients to separate groups, each peritoneal exudate (PE) sample was immediately divided into three equal aliquots, enabling within-sample (paired) comparison under the

following conditions: baseline (no incubation), incubation at 10°C without superoxide dismutase (SOD), and incubation at 10°C with SOD. One aliquot was analyzed immediately (baseline/control), the second aliquot was incubated at 10°C without enzyme addition (incubation control), and the third aliquot was treated with superoxide dismutase (SOD) and incubated at 10°C (SOD condition). Thus, although results are presented as three "groups" (control, incubation, and SOD-treated), these represent three experimental conditions applied to aliquots of the same peritoneal exudate sample obtained from each patient, rather than three independent patient cohorts. The superoxide dismutase (SOD) used in this study was a homogeneous preparation produced in the Russian Federation. The stock solution contained 3000 U/mL and was diluted in isotonic saline to achieve the working concentration in each aliquot of peritoneal exudate. For every 500 mL of exudate, 3 mL of the SOD stock solution was added, and samples were incubated at 10°C for 6 and 24 hours. The preparation was supplied in sealed sterile containers and stored according to the manufacturer's instructions. For experimental consistency, proportional volumes were applied to each aliquot based on its volume. This design minimized selection bias and enabled accurate comparison of all experimental conditions using aliquots derived from the same patient sample. This study was conducted under ex vivo conditions using a within-sample paired design. Peritoneal exudate samples were obtained intraoperatively from 30 patients with terminal peritonitis. Each sample was divided into aliquots to allow paired comparison under three conditions: baseline, incubation without SOD, and incubation with SOD.

Experimental groups

Group 1 (control group): the peritoneal exudate aliquot was analyzed immediately after collection, without incubation and without the addition of SOD. Group 2 (incubation without SOD): the peritoneal exudate aliquot was incubated at 10°C for 6 and 24 hours without the addition of SOD. Group 3 (SOD-treated group): SOD was added to the peritoneal exudate aliquot, which was subsequently incubated at 10°C for 6 and 24 hours. To minimize inter-individual variability, each peritoneal exudate sample obtained from the same 30 patients was immediately divided into three equal aliquots and processed in parallel under three experimental conditions (baseline, incubation without SOD, and incubation with SOD), enabling paired within-sample comparison.

Determination of lipid peroxidation product levels

The levels of lipid peroxidation products, including malondialdehyde (MDA), diene conjugates (DC), and total antioxidant activity (TAA), were determined in all samples (12,13). An adequate volume of peritoneal exudate was aspirated intraoperatively from each patient. For analysis, a standardized portion of each sample was isolated and divided into three equal aliquots. Samples were processed according to a predefined standardized protocol for biochemical analysis. A defined volume of isotonic solution was added to standardize viscosity and enhance centrifugation efficiency. The samples were then centrifuged at 3000 × g for 10 minutes, after which the supernatant was carefully separated from the sediment.

Biochemical measurements

Malondialdehyde (MDA) levels were determined spectrophotometrically based on the thiobarbituric acid (TBA) reaction at 532 nm. Diene conjugates (DC) were measured following lipid extraction using UV spectrophotometric detection at 232–234 nm. Total antioxidant activity (TAA) was assessed using a standard colorimetric method. All measurements were performed using a BOECO S-300 spectrophotometer (Boeckel & Co., Germany) under standardized conditions. Each sample was analyzed in triplicate to ensure reproducibility.

Statistical analysis

Normality of continuous variables was assessed using the Shapiro–Wilk test. Given that each peritoneal exudate (PE) sample was divided into three aliquots and analyzed at baseline, 6 h, and 24 h under a paired design, within-sample comparisons across timepoints and experimental conditions were performed using the Wilcoxon signed-rank test for two-timepoint

paired comparisons and the Friedman test for three-timepoint comparisons. Where applicable, independent group comparisons were conducted using the Mann–Whitney U test. Exact p-values are reported throughout. To account for multiple comparisons across lipid peroxidation markers and timepoints, Bonferroni correction was applied, and the adjusted significance threshold is reported where appropriate (Bonferroni-adjusted $\alpha = 0.05$ divided by the number of comparisons). Specifically, comparisons were performed across three biomarkers (MDA, DC, and TAA) and multiple timepoints (baseline, 6 h, and 24 h), resulting in a structured set of pairwise comparisons. Effect sizes (rank-based) and 95% confidence intervals (CIs) for mean changes were calculated and reported alongside p-values. Data are presented as median (interquartile range) or mean ± standard deviation, as appropriate. All analyses were performed using SPSS version 22 (IBM Corp., USA) and Microsoft Excel 2016. Statistical significance was defined as $p < 0.05$ after Bonferroni adjustment. No formal a priori power calculation was performed, as this was an exploratory ex vivo study. A convenience sample of 30 patients (30 PE samples, each divided into three aliquots) was used to identify biologically relevant trends. The study design was intended to reflect clinically meaningful biochemical changes in peritoneal exudate associated with oxidative stress.

Results

Lipid peroxidation products in peritoneal exudate obtained from the abdominal cavity in the terminal phase of peritonitis were analyzed in samples from 30 patients (n = 30). Statistical comparisons were performed between baseline values and incubation conditions (6 h and 24 h), as well as between samples incubated with and without SOD. Baseline values of lipid peroxidation products and total antioxidant activity are presented in Table 1. To investigate the effect of superoxide dismutase (SOD), the same peritoneal exudate samples were incubated with SOD for 6 and 24 hours. Table 2 presents the dynamics of lipid

Table 1. Lipid peroxidation product levels in peritoneal exudate obtained from the abdominal cavity in the terminal phase of peritonitis (n = 30). Values are shown as Mean ± SD (minimum–maximum).

Statistical indicators	Lipid peroxidation products		
	MDA (nmol/mL)	**DC (nmol/mL)**	**TAA (%)**
Mean±SD	2.98±0.08	2.56±0.14	21.09±0.57
Min	2.37	1.2	17.1
Max	3.5	3.3	24.5

Values are presented as mean ± SD (min–max). Units: nmol/mL (for MDA and DC) and % (for total antioxidant activity).

Table 2. Experimental dynamics of lipid peroxidation products in peritoneal exudate from patients with terminal peritonitis after incubation at 10°C with and without superoxide dismutase (SOD). Statistical comparisons were performed using the Friedman test followed by Wilcoxon signed-rank post-hoc tests.

Lipid peroxidation products	Baseline (from Table 1)	6 h (no SOD)	24 h (no SOD)	6 h (with SOD)	24 h (with SOD)	p-value
MDA (nmol/mL)	2.98±0.08 (2.37-3.5)	3.21 ± 0.09 (3.03–3.39)	3.46 ± 0.11 (3.24–3.68)	2.27 ± 0.11 (1.5–2.9)	2.02±0.10 (1.2-2.7)	<0.001
DC (nmol/mL)	2.56±0.14 (1.2-3.3)	2.79 ± 0.15 (2.49–3.09)	3.05 ± 0.16 (2.73–3.37)	2.0 ± 0.14 (0.5–2.6)	1.8±0.14 (0.5-2.5)	<0.001
TAA (%)	21.09±0.57 (17.1-24.5)	19.6 ± 0.52 (18.6–20.6)	18.1 ± 0.48 (17.1–19.1)	27.5 ± 0.46 (25–32)	30.98±0.42 (26-34.6)	<0.001

Values are presented as mean ± SD (min–max). Units: nmol/mL for MDA and DC, and % for total antioxidant activity (TAA).

peroxidation parameters under three experimental conditions (baseline, incubation without SOD, and incubation with SOD), using aliquots derived from the same 30 patients' peritoneal exudate samples rather than separate patient groups. In order to assess the specific effect of superoxide dismutase (SOD), additional aliquots of the same PE samples were incubated at 10°C for 6 and 24 hours both without and with SOD. Incubation without SOD maintained elevated levels of lipid peroxidation products characteristic of terminal peritonitis. After 24 hours of incubation with SOD, MDA levels decreased from 2.98 ± 0.08 nmol/mL (baseline) to 2.02 ± 0.10 nmol/mL ($p < 0.001$). The observed changes were associated with large effect sizes, indicating that the differences were not only statistically significant but also of substantial magnitude. Similarly, diene conjugates (DC) levels decreased from 2.56 ± 0.14 nmol/mL to 1.80 ± 0.14 nmol/mL ($p < 0.001$). In contrast, total antioxidant activity increased from 21.09 ± 0.57% at baseline to 30.98 ± 0.42% after 24 hours of incubation with SOD ($p < 0.001$) (Table 2).

In addition to statistical significance, the observed changes demonstrate clear biological and potential clinical relevance. The reduction in MDA and DC levels reflects attenuation of lipid peroxidation-mediated membrane damage, while the increase in total antioxidant activity indicates restoration of redox balance (14). The magnitude of these changes (approximately 30–32% reduction in lipid peroxidation markers and ~47% increase in antioxidant activity) suggests that SOD exerts not only statistically significant but also biologically meaningful effects on oxidative stress processes. To provide a complete and reliable comparative analysis of lipid peroxidation dynamics, aliquots of the same peritoneal exudate samples obtained from patients in the terminal phase of peritonitis were incubated at 10°C for 6 and 24 hours without the addition of SOD (incubation control). The results of these experiments are summarized in Table 2. As shown, incubation without SOD maintained elevated levels of lipid peroxidation products characteristic of terminal peritonitis. In contrast, the addition of SOD led to pronounced shifts in lipid parameters, most notably a significant decrease in malondialdehyde (MDA) and diene conjugates (DC) concentrations and a marked increase in total antioxidant activity (TAA). Importantly, incubation without SOD resulted in a progressive increase in lipid peroxidation products and a decrease in antioxidant activity, whereas the addition of SOD reversed this trend, indicating that the observed effects are specifically attributable to the enzymatic antioxidant activity of SOD rather than incubation conditions alone. It should be noted that the indicators of peritoneal exudate showed certain variability among individual patients. At the same time, the direction of changes observed after the addition of SOD was consistent across all samples; in all cases, the levels of MDA and DC decreased, while total antioxidant activity (TAA) increased. Nevertheless, the overall trend observed across all samples was characterized by a decrease in lipid peroxidation products and an increase in total antioxidant activity. Incubation of peritoneal exudate samples in the absence of superoxide dismutase (SOD) led to a progressive activation of lipid peroxidation processes. These findings are further illustrated in Figure 1, which demonstrates the comparative effects of incubation with and without superoxide dismutase (SOD) on lipid peroxidation products and total antioxidant activity after 24 hours.

As shown in Figure 1, incubation without SOD resulted in increased levels of malondialdehyde (MDA) and diene conjugates (DC) along with a decrease in total antioxidant activity (TAA), whereas the addition of SOD produced the opposite effect, confirming its significant antioxidant role. After 24 hours of incubation without SOD, MDA levels increased from 2.98 ± 0.08 nmol/mL to 3.46 ± 0.11 nmol/mL, while DC levels increased from 2.56 ± 0.14 nmol/mL to 3.05 ± 0.16 nmol/mL. At the same time, total antioxidant activity decreased from 21.09 ± 0.57% to 18.1 ± 0.48%. Incubation of peritoneal exudate samples without SOD resulted in a time-dependent increase in lipid peroxidation products and a decrease in total antioxidant activity, as shown in Table 2. The analysis of time dynamics showed that the effect of SOD addition becomes more clearly expressed with increasing incubation time. This observation indicates that the antioxidant effect of SOD has a cumulative nature over time and that prolongation of the incubation period leads to a more effective attenuation of oxidative processes. In particular, a more pronounced decrease

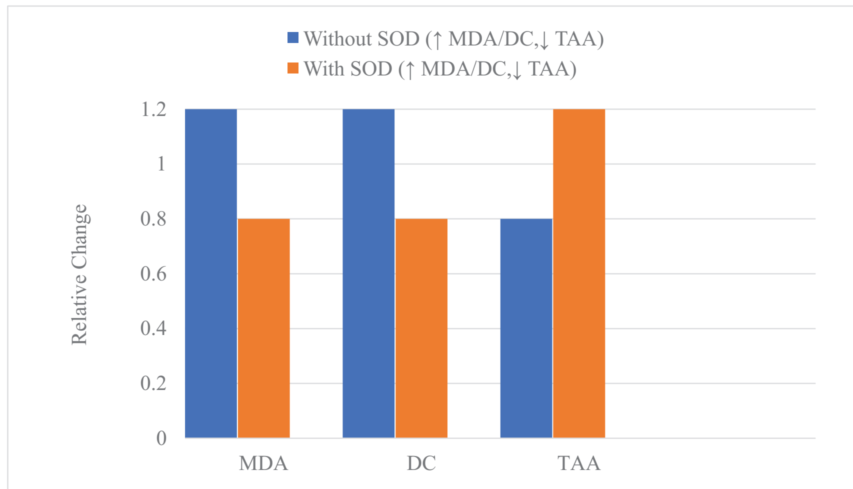

Figure 1. Effects of incubation with and without superoxide dismutase (SOD) on lipid peroxidation markers (MDA, DC) and total antioxidant activity (TAA) in peritoneal exudate after 24 h. Incubation without SOD increased MDA and DC levels and decreased TAA, indicating enhanced oxidative stress. In contrast, SOD treatment reduced lipid peroxidation markers and significantly increased TAA, reflecting attenuation of oxidative damage and improved antioxidant defense. Data are presented as mean ± SD.

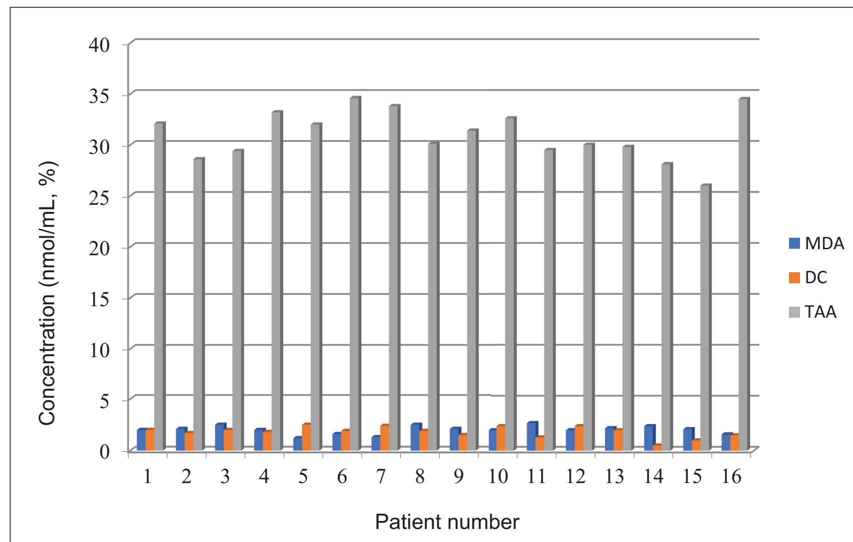

Figure 2. Distribution of malondialdehyde (MDA), diene conjugates (DC), and total antioxidant activity (TAA) in peritoneal exudate samples obtained from patients with terminal peritonitis. The figure demonstrates inter-individual variability of lipid peroxidation markers and antioxidant activity across representative patient samples. MDA and DC values are expressed in nmol/mL, whereas TAA values are presented as percentages. Representative individual patient data (n = 16 out of 30) are shown to illustrate inter-individual variability.

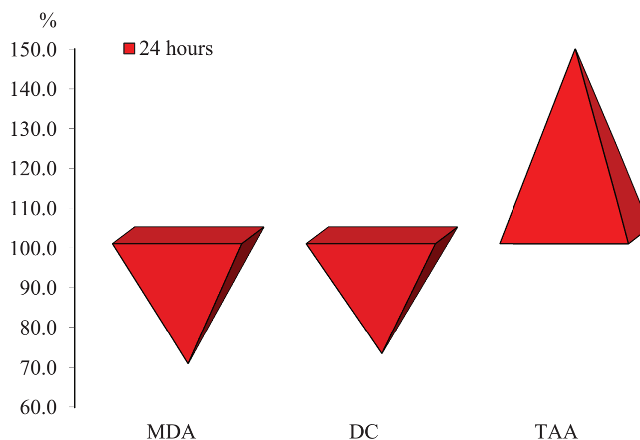

Figure 3. Relative percentage changes in malondialdehyde (MDA), diene conjugates (DC), and total antioxidant activity (TAA) in peritoneal exudate samples after incubation with and without superoxide dismutase (SOD) at 6 and 24 hours. The figure illustrates the dynamic changes in lipid peroxidation products and antioxidant activity under experimental conditions, demonstrating a decrease in MDA and DC levels and an increase in TAA following SOD treatment compared with baseline and incubation without SOD. Overall, these findings confirm the inhibitory effect of superoxide dismutase on lipid peroxidation processes and its role in enhancing antioxidant defense in peritoneal exudate.

in lipid peroxidation products was observed after 24 hours of incubation, indicating that the antioxidant effect of the enzyme increases over time. It should be noted that the indicators of peritoneal exudate showed certain variability among individual patients, as shown in Figure 2.

At the same time, the direction of changes observed after the addition of SOD was consistent across all samples; in all cases, the levels of MDA and DC decreased, while total antioxidant activity (TAA) increased. Nevertheless, the overall trend observed across all samples was characterized by a decrease in lipid peroxidation products and an increase in total antioxidant activity. These changes are not only statistically significant but also indicate a real reduction in the intensity of lipid peroxidation processes. In particular, the decrease in MDA and DC levels reflects a reduction in oxidative damage to cell membranes, while the increase in total antioxidant activity (TAA) reflects the activation of the antioxidant defense system, as illustrated in Figure 3.

Statistical note: p-values represent comparisons between baseline and incubation conditions (6 h and 24 h) as well as between incubation without SOD and incubation with SOD using paired non-parametric tests.

In contrast to the lipid peroxidation products studied above, the intensity of total antioxidant activity showed a sharply opposite trend. When peritoneal exudate obtained from the abdominal cavity during the terminal phase of peritonitis was incubated for 24 hours at 10 °C in a thermostat with the addition of SOD, the quantitative value of total antioxidant activity in this fluid reached 30.98 ± 0.42 %, with a minimum of 26% and a maximum of 34.6%. Figure 3 provides a visual representation of these findings, showing the relative percentage changes in lipid peroxidation products and total antioxidant activity after incubation with and without SOD at 6 and 24 hours.

Discussion

The results of this study demonstrate that, in terminal peritonitis, oxidative stress in peritoneal exudate

is characterized by elevated levels of lipid peroxidation products and a concomitant impairment of the antioxidant defense system. In the present study, the addition of superoxide dismutase significantly decreased the concentrations of malondialdehyde and diene conjugates, while simultaneously increasing total antioxidant activity in peritoneal exudate samples. Overall, these findings suggest that oxidative stress markers in peritoneal exudate may serve as indirect indicators of disease severity, reflecting the extent of metabolic and inflammatory disturbances in patients with terminal peritonitis. The observed changes indicate that modulation of oxidative stress within the peritoneal environment may represent a potential therapeutic strategy aimed at reducing local tissue injury and limiting the progression of the inflammatory response. Accordingly, antioxidant-based interventions, including enzymatic therapies such as SOD, may be considered as adjunctive treatment options, particularly in advanced stages of the disease. It should be noted that the results of this study are based on ex vivo incubation of peritoneal exudate. However, several limitations inherent to the ex vivo experimental model must be considered when interpreting the findings. First, ex vivo conditions do not fully replicate the complex in vivo physiological environment, where systemic factors such as blood circulation, immune responses, and neurohumoral regulation influence oxidative processes. Second, the incubation temperature of 10°C, although applied to reduce enzymatic degradation and microbial activity, does not reflect physiological conditions and may affect enzyme kinetics and reaction rates. These findings should be interpreted with caution in the context of an ex vivo model, as their applicability to clinical practice requires further confirmation in in vivo experimental models and well-designed studies. Nevertheless, the observed alterations may reflect underlying pathogenetic mechanisms of oxidative stress. Increased lipid peroxidation products are known to contribute to destabilization of cellular membranes and the progression of inflammatory reactions. In this context, Valgimigli (2023) reported that lipid peroxidation products disrupt the structural and functional integrity of cell membranes, thereby promoting the progression of inflammatory responses (6). Our results are consistent with those reported by Erkan et al. (2020). Similar findings have been described in several experimental and clinical studies investigating oxidative stress in inflammatory conditions (13). For instance, Jomova et al. (2023) demonstrated that excessive production of reactive oxygen species promotes lipid peroxidation and impairs antioxidant defense mechanisms in severe inflammatory diseases (15). These observations are in line with our findings, which show elevated levels of MDA and DC in peritoneal exudate during terminal peritonitis. It has also been reported that, in generalized peritonitis, levels of lipid peroxidation products, particularly malondialdehyde, are increased, along with alterations in antioxidant enzyme activity. Collectively, these findings indicate that lipid peroxidation products may serve as important indicators of oxidative stress in peritonitis. The significant decrease in MDA and diene conjugates following the addition of superoxide dismutase indicates attenuation of free radical–mediated reactions. The observed effects of SOD may be associated with the neutralization of superoxide radicals. By catalyzing the dismutation of superoxide anions into hydrogen peroxide and molecular oxygen, superoxide dismutase interrupts lipid peroxidation chain reactions and limits the formation of secondary lipid peroxidation products. This process has led to a weakening of lipid peroxidation chain reactions and, consequently, to a decrease in the levels of MDA and DC. These changes suggest that oxidative stress within the peritoneal environment may contribute to local tissue damage and amplification of inflammatory processes in peritonitis. Mechanistically, the observed effects of SOD may be explained by its ability to catalyze the dismutation of superoxide anions into hydrogen peroxide and molecular oxygen, thereby reducing the availability of highly reactive oxygen species that initiate and propagate lipid peroxidation. Given the central role of oxidative stress in the progression of peritonitis and systemic inflammatory response, modulation of these processes may have implications for disease severity and progression. After 24 hours of incubation, SOD supplementation was associated with an approximately 32% reduction in MDA levels, a 29% reduction in DC levels, and an approximately 46% increase in total antioxidant activity, indicating its modulatory effect on oxidative processes. In contrast, incubation without SOD resulted in increased lipid peroxidation

markers and decreased antioxidant activity, as reflected by elevated MDA and DC levels and reduced total antioxidant activity. The main novelty of this study lies in the systematic evaluation, under ex vivo conditions, of lipid peroxidation dynamics in peritoneal exudate during terminal peritonitis and the modulatory effects of superoxide dismutase on these parameters. From this perspective, SOD supplementation may contribute to the restoration of oxidative balance in peritoneal exudate and to the reduction of lipid peroxidation products. From a clinical standpoint, modulation of oxidative stress within the peritoneal environment may reduce tissue injury and limit the progression of inflammation in severe peritonitis. Therefore, antioxidant enzymes such as SOD may be considered as potential adjunctive therapeutic agents aimed at attenuating oxidative injury within the abdominal cavity. Given the central role of oxidative stress in peritonitis, enhanced lipid peroxidation in the peritoneal environment may contribute not only to local tissue damage but also to systemic metabolic disturbances, including impaired hepatic function, disruption of protein metabolism, and progression toward multiple organ dysfunction. In this context, modulation of oxidative stress through antioxidant approaches such as superoxide dismutase may have clinical relevance as an adjunctive therapy, particularly in reducing local oxidative damage and supporting metabolic stabilization in patients with terminal peritonitis. Overall, these findings underscore the potential value of targeting oxidative stress as part of a broader therapeutic strategy in the management of severe peritonitis.

Strengths and limitations

This study has several strengths, including the use of peritoneal exudate samples obtained from patients and a within-sample paired design, which minimized inter-individual variability and allowed direct comparison of experimental conditions. In addition, the study provides a focused analysis of lipid peroxidation dynamics under controlled ex vivo conditions. However, several limitations should be acknowledged. Second, the relatively small sample size may limit the generalizability of the findings. In addition, only biochemical markers of lipid peroxidation were assessed, while inflammatory cytokines and clinical severity parameters were not evaluated.

Future research directions

Future studies should focus on validating these findings under in vivo conditions and exploring the role of inflammatory and immunological parameters in peritonitis. Larger-scale clinical studies are needed to better understand the therapeutic potential of antioxidant enzymes such as superoxide dismutase. In addition, investigation of cytokine profiles and clinical outcomes may provide a more comprehensive understanding of oxidative stress modulation in peritoneal exudate.

Conclusion

This study demonstrates that lipid peroxidation processes are markedly activated in peritoneal exudate during the terminal stage of peritonitis, accompanied by impaired antioxidant defense. The findings indicate that superoxide dismutase may play a role in modulating oxidative stress and reducing lipid peroxidation intensity. These results highlight the potential therapeutic relevance of antioxidant approaches in severe peritonitis. Further studies are warranted to better define their clinical significance and therapeutic potential.

Ethical Approval: All study procedures were reviewed and approved by the Ethics Committee of Azerbaijan Medical University (protocol No. 07, March 15, 2023). The protocol entitled "The Effect of Superoxide Dismutase on Lipid Peroxidation Products and Antioxidant Activity in Peritoneal Exudate in the Terminal Phase of Peritonitis" was considered compliant with bioethical standards, and the research was authorized for implementation.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors Contribution: RK, OI, EA, NKh: experiment, review, FG, SM, AK, YSh, LB: investigation, methodology, editing, resources, writing, data curation. AA, MF, UA, MK, HA: statistical calculation, visualization. All authors contributed to the article and approved the submitted version.

Declaration on the Use of AI: None.

Consent for Publication: All authors approved the final version of the manuscript for publication.

Acknowledgements: We gratefully acknowledge the support of the Surgical Diseases Clinic of Azerbaijan Medical University and the Scientific Research Center for their assistance in clinical sample collection.

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