

Beneficial Effects of METAVITAL's MNLS-based System on Cultured Neuronal and Inflammation-mediating Cells

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ABSTRACT

Background: External environmental influences can cause an increased generation of reactive oxygen species in the body, which overwhelm the body's own antioxidant enzyme systems. The result is oxidative stress, which can damage cells and organs which then might cause neuronal dysfunction and even neurodegenerative and neuroinflammatory processes. Multidimensional nonlinear systems (MNLS) are recognized and applied as analysis and balancing systems in complementary medicine that restore the energetic and functional status of an organism. The measurement is based on biophotons. However, MNLS-based systems are not yet accepted in conventional medicine. In this animal-free study with cultured cells, the effects of the MNLS-based system from METAVITAL were investigated at the cellular level.

Experimental: Based on the knowledge of neurodegeneration and neuroinflammation, neuronal cells (SH-SY5Y) and inflammation-mediating cells (differentiated HL-60 as functional neutrophils) were used in this *in vitro* study. A single exposure for 60 minutes by the MNLS-based system with the biophoton trigger sensor consisting of a light intensity sensor and an infrared light source positioned 40 mm below the cell cultures was applied. The effect on vitality, regeneration and environmental oxidative stress of the neuronal cells as well as the effect on superoxide anion radical generation by inflammation-mediating cells was investigated. At least three independent experiments with replicates were performed.

Results: The MNLS-based system had positive effects on all parameters tested in this *in vitro* study compared with untreated controls. Neuronal cell vitality was improved by 10.1 ± 3.3 %, cell regeneration was improved by 65.9 ± 10.5 % and cell viability after oxidative stress was improved by 47.1 ± 6.8 %. Moreover, the endogenous radical generation of inflammation-mediating cells in the tissue was reduced by 18.8 ± 4.4 % (all data represent mean values \pm standard deviations). The observed effects of the MNLS-based system were significantly different from untreated controls ($p \leq 0.05$ or $p \leq 0.01$; Wilcoxon-Mann-Whitney two-tailed rank sum test).

Conclusions: Oxidative stress plays a central role in the damage of nerve cells and the development of many neurological disorders and diseases. As demonstrated in the cell-based assays presented here, the single application of METAVITAL's MNLS-based system has beneficial properties that might counteract neurodegeneration, neuroinflammation and the associated functional disorders in a complex organism, thus, maintaining and improving individual well-being and neuronal health.

Abbreviations: MNLS - Multidimensional nonlinear system

Keywords

Multidimensional nonlinear system
Environment
Neurodegenerative diseases
Neurological disorders
Neuroinflammation
SH-SY5Y cells
HL-60 cells
Vitality
Regeneration
Oxidative stress
Cell culture

Research Article

INTRODUCTION

Undesirable environmental influences such as electrosmog, industrial chemicals, xeno-biotics, air pollution, ultraviolet and ionizing radiation, and many others can cause an increased formation of reactive oxygen species in the body, which overwhelm the body's own antioxidant enzyme systems [1-4]. The result is oxidative stress, which can damage cells and organs. In the nervous system, for example, damage to lipids, proteins, and DNA can cause neuronal dysfunction and even neurodegenerative and neuroinflammatory processes [5-8]. In dementia, oxidative damage in the mitochondria, amyloid beta and tau deposits, and inflammatory processes are associated with these diseases [9,10]. Moreover, acute and chronic inflammatory processes are also related to an excess of radicals in the tissue caused by an oxidative burst of inflammation-mediating cells such as neutrophils [11,12].

Multidimensional nonlinear systems (MNLS) are accepted and applied as analysis and balancing systems in complementary medicine that restore the energetic and functional status of an organism [13-15]. The measurement is

based on the emission of biophotons [16-19]. MNLS systems are not yet accepted in conventional medicine.

In this animal-free study with cultured cells, the effects of the MNLS-based system from METAVITAL were investigated at the cellular level. Based on the knowledge of neurodegeneration and neuroinflammation, both neuronal and inflammation-mediating cell lines were used in this study.

MATERIALS AND METHODS

MNLS-based system and basic experimental setup

An MNLS-based system from METAVITAL GmbH was provided for the duration of this study. It was used in accordance with the manufacturer's instructions with the biophoton trigger sensor consisting of a light intensity sensor and an infrared light source, positioned 40 mm below the cell culture dishes or flasks (Figure 1). Exposure was always performed at 100 % PWM. The signal strength was between 86 % and 91 % and the reflection strength of the signal was always in the green level. For the experiments, the control cells

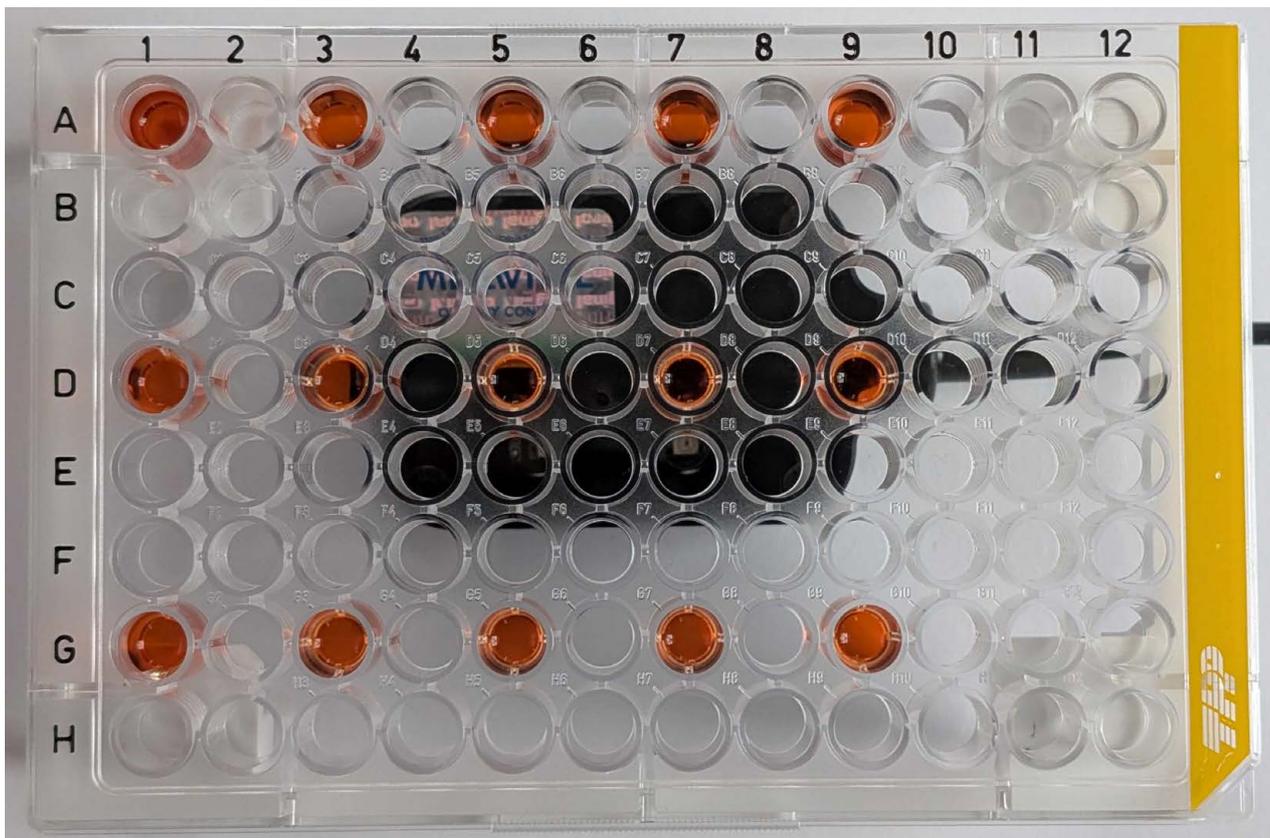


Figure 1: Experimental setup with a 96 well cell culture plate positioned 40 mm above the biophoton trigger sensor. This setup was placed in a mini incubator with 37 °C using a pH-stable culture medium. The other devices of the MNLS-based system such as the METAVITAL box and the notebook with the corresponding software for controlling the system, are not shown. The single wells containing the cells can be recognized by the orange culture medium.

and the treated cells were cultivated in separate mini incubators at 37 °C in a pH-stable culture medium (RPMI 1640/Leibovitz L-15 (1+2) supplemented with 10 % growth mixture, 20 mM HEPES buffer and standard amounts of antibiotics). The two incubators were located approximately 10 meters apart and separated from each other by several structural house walls. Experiments were performed over a period of several weeks.

Cell culture

SH-SY5Y cells are a clonal subline of a neuroepithelioma cell line that had been established in 1970 from the bone marrow biopsy of a 4-year-old girl with metastatic neuroblastoma. The cell line is a valuable in vitro model for functional studies in neurobiology and research on neurodegenerative diseases or neurological disorders [20-22].

The SH-SY5Y cells (ACC 209; DSMZ Leibniz Institute, Braunschweig, Germany) were routinely cultivated as mass cultures in a culture medium consisting of DMEM with 1.0 g/L glucose and Ham's F12 (1+1), supplemented with 10% growth mixture and the usual amounts of antibiotics. The cells for the experiments were taken from 80 to 90 % confluent mass cultures in internal passage 24 to 26.

The second cell type of this study were human promyelocytes (HL-60; ACC 3, DSMZ Leibniz Institute, Braunschweig, Germany) which were differentiated to functional neutrophils able to undergo an oxidative burst upon phorbol ester stimulation similar to primed neutrophils [23-25]. HL-60 cells were cultivated as suspension mass cultures in RPMI 1640 medium supplemented with 10 % growth mixture and standard amounts of antibiotics. The cells for the experiments were taken from mass cultures in internal passage 16 to 20.

Cultivation was always carried out in an incubator at 37 °C and a humid atmosphere of 5 % CO₂ and 95 % air. The cells were regularly transferred twice a week to new cell culture flasks at a lower cell density for further growth.

Examination of cell vitality

SH-SY5Y cells were seeded into 96-well culture plates (200 µl culture medium/well) at a cell density of 100,000 cells/well and incubated for 24 hours until the cells had completely adhered and restored their metabolism. Then, cells were treated with the MNLS-based system for 60 minutes and cultured for another 24 hours. The control cultures were handled simultaneously in the same manner without use of the MNLS-based system. For the examination of cell vitality, cells were incubated in a reaction mixture consisting of 180 µL/well of culture medium and 20 µL/well of XTT (Xenometrix, Allschwil, Switzerland). The cleavage of the dye is directly proportional to

the mitochondrial dehydrogenases activity. Finally, the optical density was measured as a difference measurement $\Delta OD = 450-690$ nm at definite time points by an Elisareader (BioTek ELx808 with software Gen 5 version 3.00) and analyzed using Microsoft Excel. Three independent experiments with at least six replicates for each experiment were performed.

Examination of cell regeneration

Cells were seeded at a density of 200,000 cells/ml into the four individual compartments of silicone 4 well-culture inserts (ibidi, Gräfelfing, Germany). The single compartments of the inserts are separated by 500 µm thick silicone bars. Due to the special adhesion area, each insert adheres firmly to the bottom of a culture dish and forms a distinct cell-free area, which the cells can colonize by migration and proliferation after removal of the silicone frame.

Upon reaching confluency within 48 hours after cell seeding and directly after removal of the insert, the cells were exposed once to the MNLS-based system for 60 minutes. The control cultures were handled simultaneously in the same manner without use of the MNLS-based system. After 15 hours of continuous incubation, cell cultures were washed with phosphate-buffered saline, fixed with methanol, stained with Giemsa methylene blue solution (Sigma-Aldrich, Deisenhofen, Germany) and were air-dried. Micrographs documenting the width of the remaining cell-free area were done at different locations for each sample. A total of 4 measurements of the remaining cell-free area was carried out for each independent test series. IKOSA AI software with artificial intelligence (Kolaido, Altenrhein, Switzerland) was used to calculate the residual cell-free area for the treated cell cultures in comparison to untreated controls. Three independent experiments were performed, each with three replicates.

Examination of environmental oxidative stress

SH-SY5Y cells were seeded into 96-well culture plates (200 µl culture medium/well) at three different cell densities (200,000, 100,000 and 50,000 cells/well) and incubated for 24 hours until the cells had completely adhered and restored their metabolism. Then, cells were treated with hydrogen peroxide concentrations ranging from 0.5 to 2 mM in the culture medium with and without a single exposure to the MNLS-based system for 60 minutes. After another 24 hours, cell survival/viability of the SH-SY5Y cells was examined by the XTT test as described above. Three independent experiments with the three different cell densities were performed with several replicate wells per experiment.

Examination of anti-inflammatory potential

Promyelocytes were cultivated as suspension mass

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cultures in special culture flasks with a vented cap (25 cm² growth area; TPP, Switzerland) so that an atmospheric gas exchange can be inhibited by turning the cap into another position. The cultured promyelocytes were differentiated into functional neutrophils by adding 1.5 vol% dimethyl sulfoxide for 6 days. On the last two days of differentiation, cells were treated with the MNLS-based system from METAVITAL for 60 minutes on each day. The control cells remained untreated. Finally, the cells of each experimental series were harvested by centrifugation (190 x g for 6 minutes) and were repeatedly washed in phosphate buffered saline with calcium and magnesium and centrifugation steps. Cells were resuspended in phosphate buffered saline with calcium and magnesium containing 10 mM glucose. 40 µl of the cell suspension aliquots were pipetted to a reaction mixture containing the tetrazolium dye WST-1 (Sigma-Aldrich, Deisenhofen, Germany) and phorbol-12-myristate-13-acetate for induction of an oxidative burst. Cells without addition of the phorbol ester served as internal controls reflecting the basal cell metabolism without stimulation. The generated reactive superoxide anion radicals in the reaction mixture caused the cleavage and color change of the dye. The amount of superoxide anion radicals present in the reaction mixture was directly related to this color change. The change in optical density was recorded at various time points up to 40 minutes as a differential measurement $\Delta OD = 450\text{-}690\text{ nm}$ by an Elisareader (BioTek ELx 808 with software Gen 5 version 3.00) and calculated with Microsoft Excel.

STATISTICAL ANALYSIS

Statistical analysis was done using the parameter-free two-tailed Wilcoxon-Mann-Whitney rank sum test and significance was determined at the 5 % ($p \leq 0.05$) and 1 % ($p \leq 0.01$) level.

RESULTS

In preliminary cell culture tests with different exposure times to the infrared light source, we determined that a duration of 60 minutes was optimal for cell activation. Longer exposure times did not change the result. Therefore, all subsequent tests were performed with a single exposure time of 60 minutes per experiment or within one day, respectively.

Cell vitality

The single exposure to the MNLS-based system from METAVITAL improved the vitality of the SH-SY5Y cells by $10.1 \pm 3.3\%$ compared to the untreated control cells (mean value \pm standard deviation). The difference to the control cells was statistically significant ($p \leq 0.05$).

Cell regeneration

The residual cell-free area after 15 hours of regeneration was only $9.4 \pm 2.3\%$ of the total area for the cell cultures treated with the MNLS-based system, while the residual area for the untreated cells was $15.6 \pm 2.7\%$ (mean values \pm standard deviations). In relation to the residual area, this corresponds to an improved regeneration by the MNLS-system of $65.9 \pm 10.5\%$ compared to untreated control cells (Figure 2). The difference was statistically significant ($p \leq 0.01$).

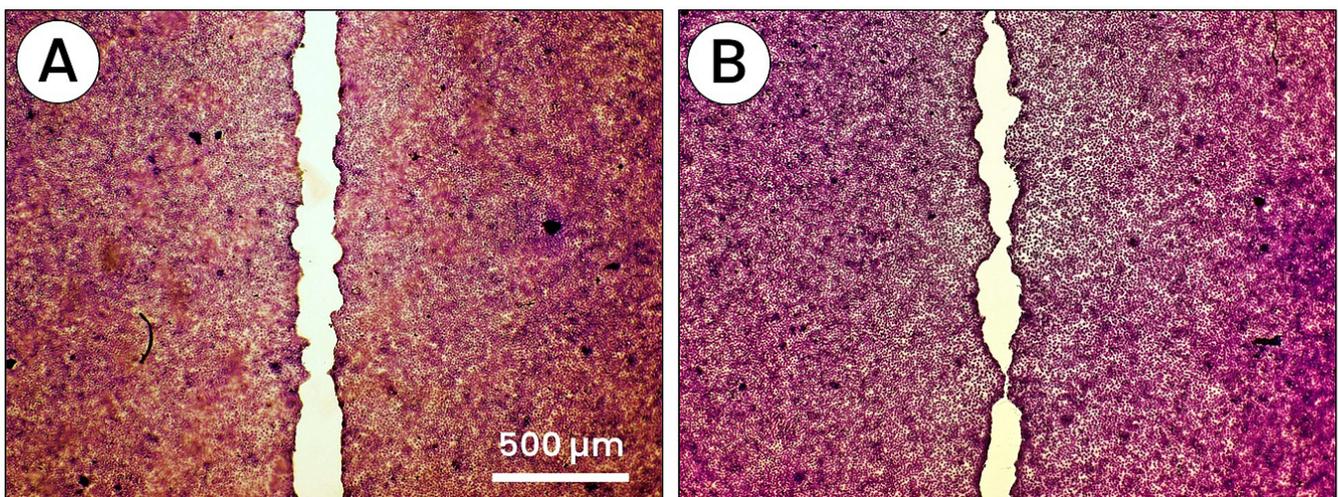


Figure 2: Microphotographic documentation of the residual cell-free area after 15 hours for untreated control cell cultures (A) compared to the cell cultures that had been exposed to the MNLS-based system from METAVITAL for one hour at the beginning of the regeneration phase (B). Olympus IX50 inverted microscope with a Planachromate 10x and an Olympus E-20 digital camera at a resolution of 5 megapixel using brightfield illumination.

Environmental oxidative stress

As expected, the viability of the cells decreased with increasing hydrogen peroxide concentration in the culture medium. Nevertheless, at all concentrations, the viability of the cells treated only once with the MNLS-based system was significantly better than that of the untreated control cells. At the highest hydrogen peroxide concentration, cell viability of cell cultures treated with the MNLS-based system was most pronounced with 61.2 ± 5.9 % cell survival compared to the untreated control with only 41.6 ± 4.3 % cell survival (mean values \pm standard deviations). This corresponds to an improved cell survival by the MNLS-system of 47.1 ± 6.8 % compared to untreated control cells. The difference was statistically significant ($p \leq 0.01$).

Endogenous radical generation

Compared to the untreated controls, exposure to METAVITAL's MNLS-based system resulted in a pronounced and statistically significant reduction in endogenous radical generation in the tissue by functional neutrophils by 18.8 ± 4.4 % (mean value \pm standard deviation; $p \leq 0.01$).

An overview on the relative measurement data demonstrating the improved beneficial effects by the METAVITAL MNLS-based system vs. untreated control cell cultures are given in Figure 3.

DISCUSSION

The results have demonstrated that the MNLS-based system is able to improve vitality of cultured neuronal cells significantly compared with untreated cells. This measurement parameter was chosen because cell vitality is a fundamental characteristic of the nervous system that plays an essential role in the improvement and preservation of health in the body. Within the complex network of cells, various metabolic pathways work together to produce energy, synthesize essential molecules, and regulate cellular functions which contribute to cell vitality [26,27].

Cell regeneration is a fundamental biological process that enables organisms to replace damaged or dead cells and thus maintain homeostasis. Promoting regeneration can result in an earlier restoration of the integrity and functionality of the affected tissue area. In most regenerating processes, the closure of a defect in a given structure requires the production of new cells. Therefore, one of the main functions of early signaling events after injury is to stimulate the production of additional cells that are able to rebuild lost or damaged structures. This is mostly done by cell proliferation, for example either proliferation of stem cells or of terminally differentiated cells [28,29]. In addition, the second fundamental cellular event during regeneration is the migration of cells [30]. Therefore, cell vitality and cell regeneration are interconnected with each other and improve the integrity and functionality of a tissue.

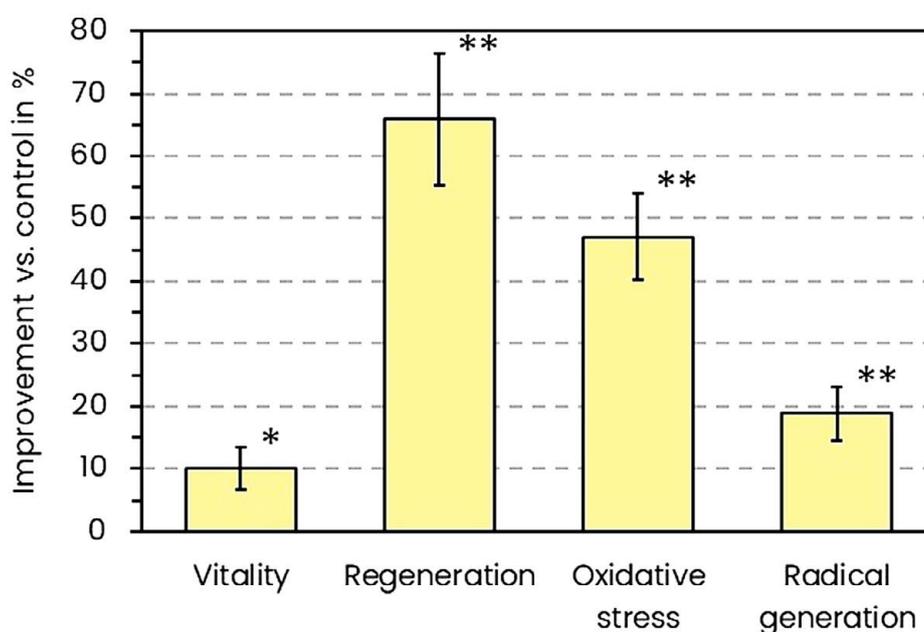


Figure 3: Summarized measurement data of all tests performed demonstrating the relative improvement by a single use of the METAVITAL MNLS-based system. Data represent mean values \pm standard deviations of at least three independent experiments with replicates each. Statistical significance is marked as follows: * $p \leq 0.05$ and ** $p \leq 0.01$ (Wilcoxon-Mann-Whitney two-tailed rank sum test).

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Physical injuries and neurodegenerative diseases often lead to irreversible damage and loss of function in the central nervous system. In mammals, such loss of function is due to the inability of these neurons to regenerate. Although the central nervous system has a limited capacity for self-healing in the early stages of embryonic development, this capacity decreases dramatically after birth [31]. Compared to the central nervous system, peripheral axons are able to regenerate after injury resulting in functional recovery and reinnervation of their target organs. However, this regenerative capacity is often incomplete and functional recovery is limited [32-35].

As shown here, the process of peripheral nerve regeneration/wound healing can be significantly stimulated by the MNLS-based system *in vitro*, thus closing a nerve gap in a shorter period of time. However, the effect is not related to neurodegenerative disorders of the central nervous system [8].

Environmental oxidative stressors are external factors from the environment that increase the production of reactive oxygen species including oxygen radicals in the body, overwhelming the antioxidant defense system and leading to oxidative damage of cell components such as DNA, proteins, and lipids. The environmental stressors include air pollution, ultraviolet and ionizing radiation, pesticides, herbicides, industrial chemicals and solvents, chemical compounds, geopathic and electromagnetic fields [36]. Due to oxidative stress induced by environmental influences affecting our body, the nervous system is one of the main targets resulting in neurodegenerative and neuroinflammatory processes causing neurological dysfunction, disorders or diseases [37-39].

A common *in vitro* model to simulate exogenous oxidative stress is the use of hydrogen superoxide as a donor for reactive oxygen species acting on cultured cells [40-42]. This *in vitro* model was also used here to examine whether the MNLS-based system of METAVITAL might be able to reduce external environmental oxidative stress. The measurement data demonstrate that the METAVITAL MNLS-based system acts as an antioxidant which is able to reduce oxidative stress by reactive oxygen species coming from the environment of the cells. In addition, the MNLS-based system is also able to reduce the generation of superoxide anion radicals by functional neutrophils and, thus, to act as an anti-inflammatory stimulus.

The observed effects after only a single application of the METAVITAL MNLS-based system could possibly be enhanced by several consecutive exposures in long-term test assays. All neuronal cell properties tested in this experimental study might also be able to improve and maintain neuronal health in a complex organism [39,43,44].

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