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ORIGINAL ARTICLE

Correlation of Electromyography Findings and Magnetic Resonance Imaging in Cervical Radiculopathies

Aleksandra Dominović-Kovačević,[1, 2] Sanja Grgić,[1, 2] Zoran Vukojević,[1, 2] Daliborka Tadić,[1, 2] Milorad Grujičić[2, 3]

Abstract

Background/Aim: Cervical radiculopathy is a clinical condition that occurs due to damage to the spinal nerve roots and manifests as pain, tingling and motor weakness of the arm muscles. Besides magnetic resonance imaging, electromyoneurography is one of the most significant diagnostic methods in the evaluation of cervical radiculopathies. The dilemma for electromyographers is determining the number of muscles necessary to test in order to obtain a reliable electromyographic finding that will detect nerve root damage. The aims of this study were to determine the correlation between electromyographic findings and magnetic resonance imaging of the cervical spine and to examine the specificity and sensitivity of electromyographic protocols that include different numbers of muscles.

Methods: Forty subjects undergoing electromyographic examination and magnetic resonance imaging of the cervical spine were analysed. Electromyography involved testing ten muscles, including the paraspinal muscles. Muscle screens were made from the tested muscles, comprising 5, 6 and 7 muscles with paraspinal muscles. Correlation of positive radiological findings with all muscle screens was performed and the specificity and sensitivity of magnetic resonance imaging with all muscle screens were determined.

Results: Optimal testing involved six muscles, including paraspinal muscles in the myotomal distribution defined by clinical presentation. Screen 6A-PS provided positive findings in 83 % of subjects. The sensitivity of magnetic resonance imaging was 79.31 %, the highest in screen 6D-PS and the same screen showed the highest specificity of 72.73 %.

Conclusion: For confirming the diagnosis of cervical radiculopathy, it is optimal to perform an electromyographic examination of six muscles, including the paraspinal muscles. Electromyographic examination is a more sensitive method in the evaluation of patients with cervical radiculopathy compared to magnetic resonance imaging, as it detects a greater number of relevant electrophysiological abnormalities even in patients without reliable morphological correlation of the lesion.

Key words: Cervical vertebrae; Radiculopathy; Electromyography; Electromyoneurography; Magnetic resonance imaging.

1. Clinic of Neurology, University Clinical Centre of the Republic of Srpska, Banja Luka, The Republic of Srpska, Bosnia and Herzegovina.
2. Faculty of Medicine, University of Banja Luka, Banja Luka, The Republic of Srpska, Bosnia and Herzegovina.
3. Clinic of Nephrology, University Clinical Centre of the Republic of Srpska, Banja Luka, The Republic of Srpska, Bosnia and Herzegovina.

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Corresponding author:
ALEKSANDRA DOMINOVIĆ-KOVAČEVIĆ
T: +387 65 301 511
E: aleksandra.dominovic-kovacevic@med.unibl.org
E: aleksandra.dominovic@kc-bl.com

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Introduction

Cervical radiculopathy is a clinical condition that occurs due to damage to the spinal nerve roots and manifests as pain, tingling and motor weakness of the arm muscles.[1] The incidence of cervical radiculopathy is estimated through population studies. A study conducted by reviewing the US military database revealed an incidence of 1.79 per 1,000 people.[2] A recent systematic review from 2020 showed that the prevalence of cervical radiculopathy ranged from 1.21 to 5.81 per 1000 individuals.[3]

The most common causes of cervical radiculopathies (in 3/4 of cases) are foraminal stenoses, which occur due to the narrowing of the intervertebral foramina. Unlike the most common aetiology in lumbar radiculopathies, bulging or ruptured disc is present in approximately 3/4 of cases.[4, 5] Other aetiologies such as traumatic vertebral fractures, infectious meningoradiculitis, neoplastic infiltrations and arteriovenous malformations are disproportionately rarer.[6] Risk factors include age, female gender, heavy physical labour, driving and operating vibrating equipment.[6-8] Cervical radiculopathy occurs due to compression and inflammation of the cervical nerve root.[4, 5, 9] The effects of direct mechanical compression are localised ischaemia and axonal damage.[5] The C6, C7 and C8 roots are most often affected.[10] The general symptoms of radicular lesions lead to the appearance of: sensory irritative symptoms and sensory deficits, segmental motor deficits and neurovegetative irritative symptoms or signs of damage, if it is a root that contains fibres of the autonomic nervous system.

When making a diagnosis, in addition to anamnesis and clinical examination, the gold diagnostic standard includes electromyoneurographic (EMNG) examination and magnetic resonance imaging (MRI) of the cervical spine.[1, 4, 11] The EMNG examination consists of two parts: electroneurography (ENG), which includes nerve conduction testing and electromyographic examination (EMG), which includes testing of various muscles innervated by cervical plexus roots.[12-14] However, the dilemma for electromyographers is how many muscles need to be tested to obtain a reliable electromyographic finding.

There are no published guidelines for the assessment and treatment of cervical radiculopathy. Recommendations are based on existing research, including systematic reviews. The most important thing is to reduce pain and enable the patient to function. Physical therapy plays a significant role and various surgical techniques such as anterior cervical decompression and fusion, cervical disc arthroplasty and posterior foraminotomy are applied in strictly selected cases.[15-23]

The aim of this study was to determine the specificity and sensitivity of EMG protocols that include different numbers of muscles and to determine the concordance/correlation of EMG findings with neuroimaging evaluations (MRI) of the cervical spine region.

Methods

The subjects consisted of a group of 40 patients (18 women and 22 men), ranging from 30 to 60 years, all showing signs and/or symptoms of cervical radiculopathy (CR). The examination was conducted at the EMG Cabinet of the Neurology Clinic, University Clinical Centre of the Republic of Srpska (UKCRS).

The age structure of the patients was limited to those up to 60 years of age, as older individuals are more likely to have positive findings and polyradicular lesions due to degenerative changes in the spine associated with aging. Registration for each patient included completing a standardised questionnaire that contained the following data: gender, age, neurological symptoms and signs (pain, sensory disturbances, localisation and distribution of pain and sensory disturbances, time of day when symptoms occur).

In addition to the standardised questionnaire, the following supplementary diagnostic procedures were used: EMNG and MRI. The EMG examination was performed three to four weeks after the onset of cervical radiculopathy symptoms. The EMG evaluation, using an extended screening protocol, included a larger number of arm and hand muscles, in accordance with myotomal maps. The EMG examination was performed on the following muscles: *deltoid, biceps brachii, triceps brachii, flexor carpi ulnaris, flexor carpi radialis, pronator teres, extensor digitorum communis, abductor pollicis brevis*, first *dorsal interosseus* and paraspinal muscles (PSM). From these muscles, selections were made including 5 muscles with PSM, a selection of 6 muscles with PSM and a selection of 7 muscles with PSM (Table 1).

Table 1: Classification of muscle groups (total of 5, 6 and 7 muscles including PSM) for testing and analysis

Muscles categories	Muscles tested
Selection 5A-PSM	MD, MTB, MPT, MAPB, PSM
Selection 5B-PSM	MBB, MTB, MEDC, MFDI, PSM
Selection 5C-PSM	MEDC, MFDI, PSM, MD, MFCU
Selection 5D-PSM	MBB, MFCR, MPT, MAPB, PSM
Selection 6A-PSM	MTB, MPT, MAPB, MD, MEDC, PSM
Selection 6B-PSM	MD, MBB, MTB, MFDI, MFCU, PSM
Selection 6C-PSM	MD, MEDC, MFCU, MFDI, MTB, PSM
Selection 6D-PSM	MFCR, MAPB, MPT, MBB, MTB, PSM
Selection 7A-PSM	MTB, MD, MAPB, MEDC, MBB, MPT, PSM
Selection 7B-PSM	MBB, MTB, MEDC, MFCU, MFDI, PSM, MD
Selection 7C-PSM	MEDC, MFDI, MTB, MAPB, MD, MFCU, PSM
Selection 7D-PSM	MFCR, MAPB, MFDI, MTB, MBB, MPT, PSM

PSM: Paraspinal Muscles; MD: Muscle Deltoid; MTB: Muscle Triceps brachii; MPT: Muscle Pronator teres; MAPB: Muscle Abductor pollicis brevis; MEDC (Muscle Extensor digitorum communis; MFDI: Muscle First dorsal interosseus; MFCU: Muscle Flexor carpi ulnaris; MFCR: Muscle Flexor carpi radialis; MBB: Muscle Biceps brachii.

A positive EMG finding was considered to be the presence of any denervation potentials (fibrillations, fasciculations, positive denervation potentials), as well as neurogenic characteristics of motor unit action potentials (MUAP): polyphasia, prolonged duration of action potentials and higher amplitude of action potentials. For the detection of muscle potentials, concentric coaxial needle disposable electrodes were used (TECA, 25 mm × 30 G). All EMNG examinations were performed using the same device, *Medelec Synergy* (*Viasys* England: Manor Way, Old Woking Surrey, GU22 9JU England) at the EMG Cabinet of the Neurology Clinic, UKCRS. All EMNG examinations were conducted by the same examiner under controlled environmental conditions (testing limb temperature above 30 ˚C).

MRI of the cervical spine was used as an additional diagnostic method. All MRI examinations were performed at the Radiology Clinic, UKCRS on a *Magnetom Avanto* 1.5 T machine by the same radiology specialist, who was specifically trained for MRI work. The following parameters were analysed: degenerative changes of the spinal vertebrae (presence of osteophytes, uncovertebral and zygapophyseal joint arthrosis), protrusions of the corresponding level discs and the presence of periradicular cysts.

Statistical analysis

The data were analysed using descriptive (mean and standard deviation) and analytical (Student's t-test, Chi-Square) methods. Sensitivity and specificity were determined in accordance with generally accepted calculations.[24] Statistical significance was determined using Fisher's exact test. Differences were considered statistically significant if $p < 0.05$. Statistical analyses were performed using IBM SPSS version 25.0.

Results

This study included patients with the following demographic features (Table 2). The average age of the subjects was 45.0 ± 7.43 years. Based on the results of the questionnaire the following results were recorded.

Table 2: Patient demographics by age range and gender

Age range	Male	Female	Total (n)	Total (%)
50-60	9	10	19	47.5
40-49	9	7	16	40.0
30-39	4	1	5	12.5
Total	22	18	40	100.0

The results of this study have shown that 37 subjects (92.5 %) experienced more pronounced pain and sensory disturbances at night, while only three subjects (7.5 %) had more pronounced pain and sensory disturbances during the day. The largest number of subjects, 21 (52.5 %), had hypoalgesia in the C7 dermatome, followed by ten subjects (25 %) with hypoalgesia in the C6 dermatome, four subjects (10 %) with hypoalgesia in the C5 dermatome and three subjects (7.5 %) in the C8 dermatome (Table 3).

Elevated tone of the paravertebral cervical muscles was present in 26 subjects (65 %). All subjects had limited mobility in the cervical segment of the spine in different positions (Table 4). The largest number of subjects, 14 (35 %), had a weakened triceps brachii reflex, five subjects (12.5 %) had a weakened biceps brachii reflex and only one subject (2.5 %) had a weakened brachioradialis reflex.

A positive EMG finding included the presence of denervation potentials as well as the analysis of MUAP, which includes the analysis of action potential duration, reduction of interference pattern and presence of polyphasia within different selections of five, six and seven muscles that included PSM. Results were obtained three weeks

Table 3: Pain localisation and distribution based on time of day

Pain distribution	N	Day	Night
Pain in cervical region spreading to shoulder	16	2	15
Pain in cervical region spreading to upper arm	13	0	12
Pain in cervical region and through whole arm	11	1	10
Total	**40**	**3**	**37**

Table 4: Restricted cervical segment mobility in various positions

Mobility in the cervical segment	Number of patinets	Share of affected patients (%)
Limitid AF	2	5
Limitid RF	3	7.5
Limited LF	1	2.5
Limited RF and LF	14	35
Limited AF and LF	14	35
Limited AF and RF	5	12.5
Limited AF, LF and RF	1	2.5
Total	**40**	**100**

Note: AF: anteflexion; RF: retroflexion; LF: lateroflexion.

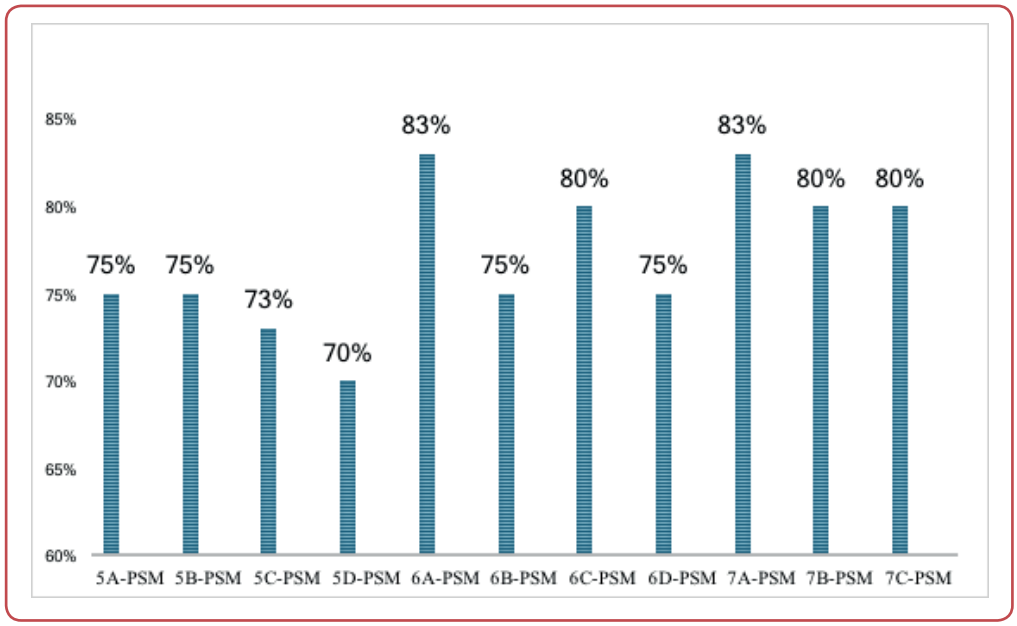

Figure 1: Electromyographic (EMG) analysis of classified muscle groups of five, six and seven muscles including paraspinal muscles (PSM)

after the onset of subjective symptoms. Considering the above and analysing all muscle screens with five, six and seven muscles with PSM, it was found that screens including five muscles, 5A-PS and 5B-PS, had positive findings in 75 % of subjects, while the screen 6A-PS (which included six muscles and PSM) and the screen 7A-PS (which included analysis of seven muscles including PSM) provided positive findings in 83 % of subjects each (Figure 1).

Analysis of the findings obtained from the MRI examination of the same patients showed that a total of 26 (65 %) had a positive result, which included not only disc herniations but also degenerative changes in the spinal vertebrae in terms of the presence of osteophytes, uncovertebral joint arthrosis, zygapophyseal joint arthrosis, periradicular cysts and spinal canal stenosis. Among the 26 positive findings, 13 (32.5 %) subjects had a disc herniation at various levels, while the other

13 (32.5 %) positive findings included periradicular cysts and spondylodeformative changes in the uncovertebral and facet joints.

Analysing the segmental distribution of positive MRI findings, which included the presence of intervertebral disc herniations, periradicular cysts and spondylodeformative changes, it was found that at the C6-C7 level, there were 14 (35 %) positive findings. It is noted that at certain levels, both disc herniations, periradicular cysts and spondylodeformative changes were present simultaneously. This was followed by the C5-C6 level with 12 (30 %) positive findings, the C7-C8 level with ten (25 %) positive findings and the least number of positive findings were at the C4-C5 level with four (10 %).

The correlation between EMG findings and MRI was conducted among all muscle screen combinations with positive MRI findings. The analysis demonstrated high statistical significance for screens 6D-PS and 7D-PS, with $p < 0.002$ (Table 5).

Table 5: Correlation of all muscle screens with paraspinal muscles (PSM) and magnetic resonance imaging (MRI)

MRI + screen	Degree of concordance between muscle screens with PSM and MRI	Chi-square (p-value)
MRI + 5A – PSM	72.5 %	0.015
MRI + 5B – PSM	72.5 %	0.019
MRI + 5C – PSM	65.0 %	0.144
MRI + 5D – PSM	75.0 %	0.006
MRI + 6A – PSM	75.0 %	0.007
MRI + 6B – PSM	72.5 %	0.019
MRI + 6C – PSM	72.5 %	0.019
MRI + 6D – PSM	77.5 %	0.002
MRI + 7A – PSM	75.0 %	0.007
MRI + 7B – PSM	72.5 %	0.019
MRI + 7C – PSM	72.5 %	0.019
MRI + 7D - PSM	77.5 %	0.002

Table 6: Sensitivity and specificity of magnetic resonance imaging (MRI) findings and muscle screens with paraspinal muscles (PSM)

MRI + screen	Sensitivity (%)	Specificity (%)
MRI + 5A – PSM	77.76 %	61.54 %
MRI + 5B – PSM	75.86 %	63.64 %
MRI + 5C – PSM	73.08 %	50.00 %
MRI + 5D – PSM	78.57 %	66.67 %
MRI + 6A – PSM	76.67 %	70.00 %
MRI + 6B – PSM	75.86 %	63.64 %
MRI + 6C – PSM	75.86 %	63.64 %
MRI + 6D – PSM	79.31 %	72.73 %
MRI + 7A – PSM	76.67 %	70.00 %
MRI + 7B – PSM	75.86 %	63.64 %
MRI + 7C – PSM	75.86 %	63.64 %
MRI + 7D - PSM	79.31 %	72.73 %

Analysis of the different muscle screens and positive MRI findings showed a sensitivity of 79.31 % for muscle screens 6D-PS and 7D-PS and a specificity of 72.73 % for the same screens (Table 6).

Discussions

Apart from diabetic polyneuropathies and compressive neuropathies such as carpal tunnel syndrome, radiculopathies (cervical or lumbosacral) represent one of the three most common reasons why patients are referred for electromyoneurography.[25] The cervical region is the second most common region of the spine (immediately after the lumbosacral region) where degenerative changes or disc herniations lead to root lesions. They account for 5-36 % of all radiculopathies. Although there are many reports on the incidence of lesions in individual roots, early studies indicate that the most common lesion is of the C7 root, accounting for 70 % of all cervical radiculopathies, followed by C6 root lesions with an incidence of 19-25 %, C8 lesions with 4-10 % and C5 lesions with 2 %.[1,4,5,8,11] However, more recent publications indicate the involvement of the C7 root with 56 % and the C5 root with 14 %.[26,27]

Cervical radiculopathies, caused by disc herniation or spondylosis, are the most common cause of neck and upper limb pain and have a significant impact on overall health.[22] Although the first articles on cervical spondylosis, disc herniation and radiculopathies can be found from the 1950s, there are still many controversies regarding diagnostic procedures and treatment methods for cervical radiculopathies, which led us to conduct this study. More than half of the total number of subjects in this study were men. The greater representation of males was confirmed in studies by Lauder et al[28] on a group of 175 subjects and by Matsumoto et al[29] on 497 subjects. The average age of the subjects was 45 years, with the majority (47.5 %) in the age range of 50-60 years and the least (12.5 %) in the age range of 30-39 years.

Apart from MRI, EMG is one of the most signif-

icant diagnostic methods used in the evaluation of cervical radiculopathies. Lauder et al were the first to conduct a study on the optimal number of muscles required for EMNG examination to confirm lumbosacral and cervical radiculopathy. In later periods, an analysis of individual muscles was conducted and the most common abnormalities in the muscles were used to form the optimal number of muscles (from 2 to 10) in the evaluation of cervical radiculopathies. The concept of EMG screening encompasses the possibility of detecting changes and electrophysiological confirmation of radiculopathies.[28]

In the assessment of suspected radiculopathies, EMG is usually performed on both limbs and PSM. The involvement of PSM in the examination is critically important as it indicates whether the pathological process is localised above or below the level of the brachial plexus. The relationship between spontaneous activity in PSM and the duration of symptoms has been investigated in many studies, which describe that spontaneous activity in PSM begins to appear within 7 to 10 days and in the distal muscles within 3 to 6 weeks.[12, 13, 17, 28, 30] In line with the aforementioned, presented EMG examination of different combinations of muscle screens with five, six and seven muscles including PSM showed 83 % positive EMG findings in the 6A-PS screen.

Dillingham et al conducted a study on 101 subjects in multiple centres in the USA with different muscle screens that included PSM and concluded that the optimal number of muscles necessary for identifying cervical radiculopathy is six, including PSM.[14] The results of presented study are consistent with these findings. It was also obtained similar results in the screen with seven muscles including PSM but believe that due to the discomfort and inconvenience for the patient, as well as for optimal use of the diagnostic procedure, it is optimal to perform a screen with six muscles including PSM.

Neuroimaging in the form of myelography, CT, or MRI diagnostics, together with neurophysiological testing, is traditionally used in the evaluation of patients with cervical radiculopathy. High-resolution MRI has become the method of choice for cervical radiculopathies. This diagnostic method has a high sensitivity for detecting disc lesions, which allows for the visualisation of degenerative processes, whether in symptomatic or asymptomatic patients.[6, 31]

The correlation of EMG findings was performed among all muscle screen combinations with positive MRI findings, where the highest concordance (75 %) was achieved with the five-muscle screen with PSM in combination 5D-PS. In the six-muscle screen with PSM, a concordance of 77.5 % was achieved with combination 6D-PS and the same concordance was achieved in the seven-muscle screen with PSM in combination 7D-PS. Nardin et al conducted a retrospective study on 47 subjects with clinical signs of cervical and lumbosacral radiculopathy, where both EMNG and MRI examinations were performed. Pathological findings on MRI were found in 53-60 % of subjects and the concordance between EMNG and MRI was confirmed in 60 % of subjects. The sensitivity of EMG findings in the group of subjects with probable cervical radiculopathy was 29 % and in the group with confirmed cervical radiculopathy, the sensitivity was 72 %.[32] In presented study, there were 65 % pathological findings on MRI, which is within the range of previous studies that found the number of positive findings to be 53-60 %. Analysing the concordance of EMG and MRI, a concordance of 77.5 % in the 6D-PS screen was obtained, which is higher than previous studies as a larger number of different combinations of muscles with PSM was tested. In this study, depending on the screens, concordance was ranging from 65 % to 77.5 %.

In this study, the sensitivity and specificity of MRI findings was analysed in relation to different muscle screens, obtaining the highest sensitivity of 79.31 % for screens 6D-PS and 7D-PS and the highest specificity of 72.73 % for the same screens. Due to varying data on the sensitivity and specificity of EMG and MRI, Robinson concluded from his analysis of studies and articles that MRI and EMG provide different information about the same problem. MRI gives us information about the anatomical relationships of cervical spine structures and has high sensitivity, but specificity is around 50 %, while EMG provides information about nerve root damage.[33] In the work of Douglas et al, the significance of EMNG is highlighted as a key examination for the treatment and further recovery of the patient.[34] The results of presented study can help resolve the dilemma of how to diagnostically treat a patient with cervical radiculopathy, a dilemma also posed in the work of Coker and colleagues.[35]

Conclusion

For the proper diagnosis of cervical radiculopathy, it is optimal to test six muscles including PSM. The highest number of positive EMG findings (83 %) is obtained when testing the following muscles: *deltoid, pronator teres, triceps brachii, extensor digitorum communis, abductor pollicis brevis* and PSM. EMNG examination is a more sensitive method for evaluating patients with cervical radiculopathy compared to MRI examination, as it detects a greater number of relevant electrophysiological abnormalities, even in patients who do not have a reliable morphological correlate of the lesion. The analysis of different muscle screens and positive MRI findings showed that the sensitivity of MRI is 79.31 %, highest in screen 6D-PS and for the same screen, the highest specificity of MRI findings is 72.73 %.

Ethics

The study was approved by the Ethics Committee of the University Clinical Centre of the Republic of Srpska, decision number 01-19-479-2/24, dated 28 from November 2024. All patients signed informed consent before entering the study. All the data obtained from this study were stored according to the Law on Protection of Personal Data, adhering to the principle of the Declaration of Helsinki.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

Author ORCID numbers

Aleksandra Dominović Kovačević (ADK):
0009-0003-7489-6823
Sanja Grgić (SG):
0009-0001-0326-2562
Zoran Vukojević (ZV):
0000-0001-8998-2634
Daliborka Tadić (DT):
0000-0002-6207-7906
Milorad Grujičić (MG):
0009-0007-9076-554x

Author contributions

Conceptualisation: ADK, SG, ZV, DT, MG
Methodology: ADK, SG, ZV, DT, MG
Investigation: ADK, SG, ZV, DT, MG
Data curation: ADK, SG, ZV, DT, MG
Writing - original draft: ADK, SG, ZV, DT, MG
Writing - review and editing: ADK, SG, ZV, DT, MG

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