



## Original article

## Application of MRI for diagnosis of selected diseases and disorders in patients admitted to the teaching hospital in Olsztyn

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## ABSTRACT

**Introduction:** Early and accurate identification of diseases and disorders is critical for patients and medical staff. Magnetic resonance imaging (MRI) offers a wide range of diagnostic applications to fulfill these expectations.

**Aim:** This study aimed to determine the incidence of selected diagnoses and evaluate the population of patients examined with an MRI during the years 2011–2015 at the University Clinical Hospital in Olsztyn (UCH).

**Material and methods:** The retrospective analysis of 5587 MRI scans and 5454 patients diagnosed in the MRI Laboratory at UCH was performed. Disease categories were assigned according to the International Statistical Classification of Diseases and Related Health Problems (ICD-10). SPSS software was used to determine the incidence of specific diagnoses and descriptive variables of the studied population.

**Results and discussion:** More women (61%) than men (39%) were enrolled, and the diseases of the nervous system (G-letter-coded category) were predominant with one-third of patients presenting with nerve root and plexus disorders. Benign neoplasms of the nervous system were also diagnosed, but those results are beyond the scope of this article. Among symptoms, signs and abnormal clinical and laboratory findings not elsewhere classified mostly dizziness and giddiness were found, and injuries and consequences of external causes included mostly dislocations, sprain and strain of joints and ligaments of knee.

**Conclusions:** The total number of MRI-diagnosed females was higher in all disease categories and age-groups, with the exception of young- and middle-aged adults 31–60 years of age in the category of injuries and consequence of external causes.

## 1. INTRODUCTION

Magnetic resonance imaging (MRI) is a noninvasive and safe medical technique, generating a large volume of data over a short period of time.<sup>1</sup> During the last decade, the most popular examination areas included the spine and head. Those scans make up more than 50% of all studies.<sup>2</sup> The most commonly applied MRI technique was concerned with the central nervous system (CNS), backbone and spine disorders, disorders of the extremities and cardiovascular system diseases.<sup>3,4</sup> At emergency departments, often nearly half of all the scan numbers are performed for a head diagnostic.<sup>5</sup> The MRI application is most beneficial in brain and spinal examinations for both adult and pediatric patients. The benefits of MRI scanning are mostly confirmed in the head, neck, abdomen, pelvis, chest and breast areas, the musculoskeletal system and prenatal diagnostics.<sup>6</sup>

When compared to computed tomography (CT), MRI shows more anatomic details of the nervous system, which makes it a great tool for the examination of abnormalities and disorders of the CNS. In traumatic joint injuries, the traditional methods of diagnostics such as physical examination and X-ray may be insufficient, whereas MRI provides excellent spatial and contrast resolution of the intra- and extra-articular anatomical structures.<sup>7</sup> MRI is also a method of choice in examinations of knee injuries and it is mostly preferable in diagnostics of meniscal and cruciate ligaments of the knee.<sup>8</sup> Traumatic injuries of the knee joint are very common. In many sport disciplines, injuries of the lower limb occur in more than 50% of all cases, with the most common injury sites being the knee, ankle and thigh.<sup>9</sup>

It has been suggested that the aging of society significantly increases the use and costs of high-technology diagnostic tools such as CT and MRI; not all authors, however, agree with that statement.<sup>10</sup> The general trend shows the increasing use of advanced imaging technologies in patients 55–64 years of age,<sup>11</sup> and it has also been noticed that female patients participated in advanced imaging diagnostics more than males.<sup>10</sup>

## 2. AIM

The aim of the present study was to determine the incidence of the most common MRI applications in selected diagnostic categories and evaluate the population of patients examined with a Siemens Magnetom Trio A Tim System at the University Clinical Hospital in Olsztyn (UCH) between 2011 and 2015.

## 3. MATERIAL AND METHODS

The study population included patients examined by the Siemens Magnetom Trio A Tim System MRI scanner at the UCH during the years 2011–2015. The age of the studied population ranged from 2 to 92 years of age, and included

61% women and 39% men. The data was collected at the MRI Laboratory of the UCH. Specific diagnoses, number of scans, number of patients, and patient characteristics were analyzed in three categories of diseases: diseases of the nervous system (G), symptoms, signs and abnormal clinical and laboratory findings not elsewhere classified (R), as well as injuries and consequences of external causes (S).

Methodology of the diagnosis and patients coding procedure as well as the data processing were described in the previous paper.<sup>12</sup> The  $\chi^2$  test was used to determine the level of significance in chosen areas if the number of observations was more or equal to 5 in each group.

## 4. RESULTS

Overall, 13 298 MRI scans were conducted between the years 2011–2015. In total, 58% of all visits were diseases of the musculoskeletal system and connective tissue in the M-letter-coded category according to ICD-10. The other most frequently represented disease categories were G – diseases of the nervous system; C and D – neoplasms; R – symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified and S – injuries and consequences of external causes. The representation of subgroups in the total number of visits is shown in Table 1. The M category data has been excluded, and the number of 5587 visits and 5454 patients has been extensively analyzed. Disease categories C and D were not closely analyzed in this particular study.

In the analyses presented below, the frequency of the chosen diagnoses excluding M, and with the cumulative number of patients with rare diagnostic codes as ‘other’ are shown. Table 2 shows the number of patients with a G, R, or S diagnosis in the context of gender and age. The S diagnosis was connected with males in the age range of 31–60 who had injuries. In the remaining subgroups, the number of female patients were larger than number of male patients. The total number of male patients was higher than the total number of female patients in the S subgroup.

The R-subgroup is a very heterogenic category including symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R00–R99), and the S-subgroup includes injury, poisoning and certain other consequences of external causes (S00–S99). The category ‘other’ summarizes rare diagnoses A, B, E, F, H, I, J, K, L, N, Q, T and Z. The  $\chi^2$  test showed statistically significant differences in diagnostic distribution in females and males aged 31–60 in comparison to the left over subgroups.

The annual distribution of patients with an MRI-diagnosed disease in the study period is shown in Table 3. The number of patients diagnosed with the G code showed the same trend as the observed numbers of examinations, which means that an increase in the number of examinations was paralleled by an increase in the number of patients with G-diagnoses. The number of patients with R and S diagnostic codes showed fluctuations not connected with an increase or decrease in performed MRI scans.

**Table 1. Number of MRI examinations during the 5-year period 2011–2015.**

Group of diagnoses	M	C	D	G	R	S	Other	Total
Number of visits	7711	118	722	2903	487	340	1017	13298
[%]	58.0	0.9	5.4	21.8	3.7	2.6	7.6	100

Source: MRI Laboratory, University Clinical Hospital in Olsztyn 2011–2015.

**Table 2. Number of patients with G, R, S ICD-10 diagnosis codes during the 5-year MRI utilization of 2011–2015.**

Age range	Gender	G	R	S	Total
≤30	Females	85	13	26	177
	Males	74	6	16	162
31–60 <sup>a</sup>	Females	1401	236	107	2394
	Males	749	123	146	1477
≥61	Females	350	69	25	783
	Males	197	35	18	461
Total	Females	1836	318	158	3354
	Males	1020	164	180	2100
Total		2856	482	338	5454

Source: MRI Laboratory, University Clinical Hospital in Olsztyn 2011–2015. Comments: <sup>a</sup>  $P < 0.05$ .

**Table 3. Annual number of MRI examined patients between 2011–2015.**

Year	G	R	S	Total	Average	Median	SD
2011	359	125	79	707	141	103	112
2012	569	77	32	897	179	77	199
2013	732	109	92	1665	333	170	263
2014	647	69	78	1120	224	158	215
2015	549	102	57	1065	213	164	175
Total	2856	482	338	5454	1091	792	911

Source: MRI Laboratory, University Clinical Hospital in Olsztyn 2011–2015.

Specific diseases and health disorders diagnosed with MRI in the years 2011–2015 are described below.

#### 4.1. MRI in the diagnosis of the nervous system (G00–G99)

Within the diseases of the nervous system, 126 individual diagnostic codes belonging to 11 categories were recorded in a group of 2856 patients (Table 2), and 2903 MRI scans were collected (Table 1) which constituted 21.8% of the total number of examinations. In the G-letter-coded category, the most frequently diagnosed were episodic and paroxysmal disorders, nerve, nerve root and plexus disorders, other disorders of the nervous system, and there were significant differences in the numbers of female and male patients. The most frequently diagnosed specific disease types were nerve root and plexus disorders (G54–G54.9), with the total number of patients being  $n = 869$  (Table 4), which represented 30.4% of all patients in the G-letter-coded category (Figure 1). Figure 2 shows the cumulative number of patients in the context of age and gender.

#### 4.2. MRI in the diagnosis of the symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R00–R99)

In the symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified category, 26 individual codes belonging to 8 categories were recorded in a group of 482 patients (Table 2), and 487 MRI scans were collected (Table 1). Figure 3 shows the cumulative number of patients in the context of age and gender.

In the R-letter-coded category, the most frequent diagnosis in both females and males were two subgroups including symptoms and signs involving cognition, perception, emotional state and behaviour (R40–R46) and general symptoms and signs (R50–R69). The most common specific diagnosis in the category of symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified were dizziness and giddiness (R42); which was found in 205 patients (42.5% of all patients in the R category) as shown in Table 4, Figure 1.

**Table 4. G, R, S ICD-10 diagnosis codes in the context of demographic characteristics of the MRI diagnosed population between 2011–2015.**

	Females				Males				Total
	≤30	31-60	≥61	Total	≤30	31-60	≥61	Total	
<b>Diseases of nervous system (G)</b>									
G54–G54.9	5	417	101	523	5	263	78	346	869
G44–G44.8	33	362	79	474	13	119	30	162	636
G40–G40.9	18	155	14	187	25	102	7	134	321
G93–G93.9	6	92	31	129	5	34	14	53	182
G94–G94.8	7	74	20	101	8	56	12	76	177
G55–G55.3	1	44	17	62	1	45	11	57	119
G98	0	36	12	48	5	30	8	43	91
G35	0	33	4	37	1	11	1	13	50
G45–G45.9	2	23	10	35	1	9	3	13	48
G96–G96.9	1	23	5	29	2	14	2	18	47
G99–G99.8	3	14	8	25	1	7	1	9	34
Other	9	128	49	186	7	59	30	96	282
<b>Total</b>	<b>85</b>	<b>1401</b>	<b>350</b>	<b>1836</b>	<b>74</b>	<b>749</b>	<b>197</b>	<b>1020</b>	<b>2856</b>
<b>Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R)</b>									
R42	3	95	35	133	1	56	15	72	205
R51	5	59	11	75	3	31	7	41	116
R29–R29.8	1	48	8	57	1	16	6	23	80
R10–R10.1	0	19	9	28	0	11	6	17	45
Other	4	15	5	24	1	9	1	11	35
<b>Total</b>	<b>13</b>	<b>236</b>	<b>68</b>	<b>317</b>	<b>6</b>	<b>123</b>	<b>35</b>	<b>164</b>	<b>481</b>
<b>Injuries and consequences of external causes (S)</b>									
S83–S83.7	15	40	7	62	7	63	3	73	135
S06–S06.5	0	4	1	5	2	15	3	20	25
S23	2	9	2	13	1	9	1	11	24
S43–S43.4	1	4	2	7	2	11	3	16	23
S13–S13.4	0	13	2	15	2	2	2	6	21
S46–S46.0	0	4	1	5	0	7	2	9	14
Other	8	33	10	51	2	39	4	45	96
<b>Total</b>	<b>26</b>	<b>107</b>	<b>25</b>	<b>158</b>	<b>16</b>	<b>146</b>	<b>18</b>	<b>180</b>	<b>338</b>

Source: MRI Laboratory, University Clinical Hospital in Olsztyn 2011–2015.

#### 4.3. MRI in the diagnosis of injuries and consequences of external causes (S00–S99)

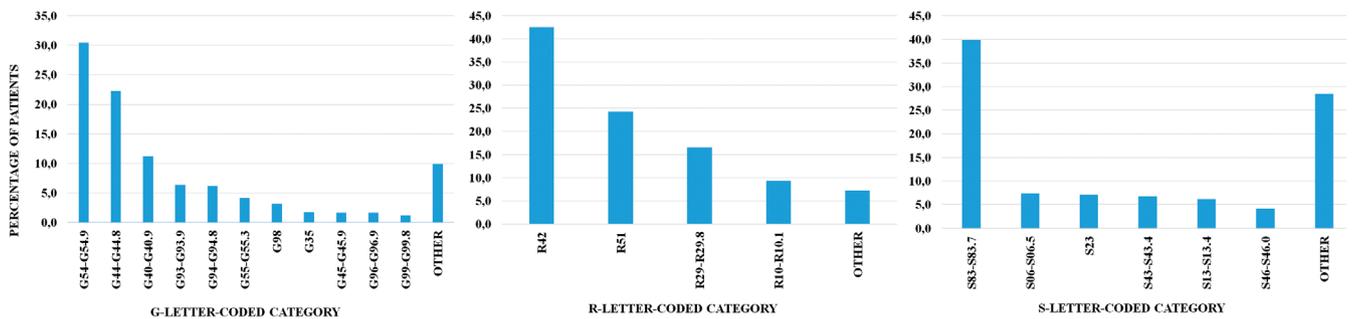
In the injuries and consequences of external causes category, 58 individual codes belonging to 10 categories were recorded in a group of 338 patients (Table 3), and 340 MRI scans were collected (Table 1). Figure 4 shows the cumulative number of patients in the context of age and gender. In this disease group, male patients were more frequently diagnosed with limbs and head injuries. Patients under 40 years of age were predominantly diagnosed with injuries of the head and with injuries of the knee and lower leg, whereas in the category of injuries of the shoulder, upper arm and thorax, a larger number of patients 51–60 years old were recorded. Injuries of the elbow and forearm were typical for male patients and injuries of the hip, thigh, wrist

and hand were typical for female patients.

The most frequent specific diagnose types were dislocation, sprain and strain of joints and ligaments of the knee (S83–S83.7), with the total number of patients being  $n = 135$  (Table 4), which represented 39.9% of all patients in the S-letter-coded category (Figure 1).

## 5. DISCUSSION

There is evidence that early and easy access to diagnostic equipment and physicians' experience have an important impact on the type, frequency and adequateness of diagnostic imaging applications. It has also been shown that the appropriateness of using imaging techniques varies with age,



**Figure 1.** Percentage of patients with specific diagnose G-, R-, S-letter-coded category during 5-year MRI use. **Comments:** G54 Nerve root and plexus disorders, G44 Other headache syndromes, G40 Epilepsy, G93 Other disorders of brain, G94 Other disorders of brain in diseases classified elsewhere, G55 Nerve root and plexus compressions in diseases classified elsewhere, G98 Other disorders of nervous system, not elsewhere classified, G35 Multiple sclerosis, G45 Transient cerebral ischaemic attacks and related syndromes, G96 Other disorders of central nervous system, G99 Other disorders of nervous system in diseases classified elsewhere, R42 Dizziness and giddiness, R51 Headache, R29 Other symptoms and signs involving the nervous and musculoskeletal systems, R10 Abdominal and pelvic pain, S83 Dislocation, sprain and strain of joints and ligaments of knee, S06 Intracranial injury, S23 Dislocation, sprain and strain of joints and ligaments of thorax, S43 Dislocation, sprain and strain of joints and ligaments of shoulder girdle, S13 Dislocation, sprain and strain of joints and ligaments at neck level, S46 Injury of muscle and tendon at shoulder and upper arm level.

gender, size, patient's physical limitations, as well as the symptoms and conditions investigated.<sup>6</sup>

Although cardiovascular disorders are commonly diagnosed using MRI and the worldwide literature shows an increased trend of MRI angiography utilization,<sup>13</sup> they were not as frequently diagnosed in our study group as would be expected. The significance of this health problem in the general population was therefore not mirrored in the analysed MRI examinations of our study population. The MRI is considered to be a very useful technique in the diagnosis of cardiac, vessel and visceral organs anomalies,<sup>14</sup> and the development of such MRI applications at the UCH could further benefit its patients.

In the examined population, the number of patients sent for MRI diagnostics due to headache symptoms were appreciable (G44, R51) (Table 4, Figure 1). Some authors suggest that neuroimaging methods should not be routinely ordered in the case of initial reports of headache. This is in contrast to patients with a neoplasm suspicion, vascular malformations, posttraumatic or focal brain lesions; who must be diagnosed with a neuroimaging technique since this could be a life-saving diagnostic application.<sup>15</sup>

The MRI technique provides much more precise data in brain examinations and diagnostics than CT.<sup>16</sup> Furthermore, it shows advantages in acute ischemia and chronic haemorrhage detection. For these reasons, it should be preferred for the diagnosis of suspected acute stroke.<sup>17</sup> MRI has had a major impact on the diagnosis and understanding of multiple sclerosis and it is routinely used in multiple sclerosis diagnostics<sup>18–20</sup> and in epilepsy.<sup>21</sup> Both multiple sclerosis and epilepsy were diagnosed in the studied population.

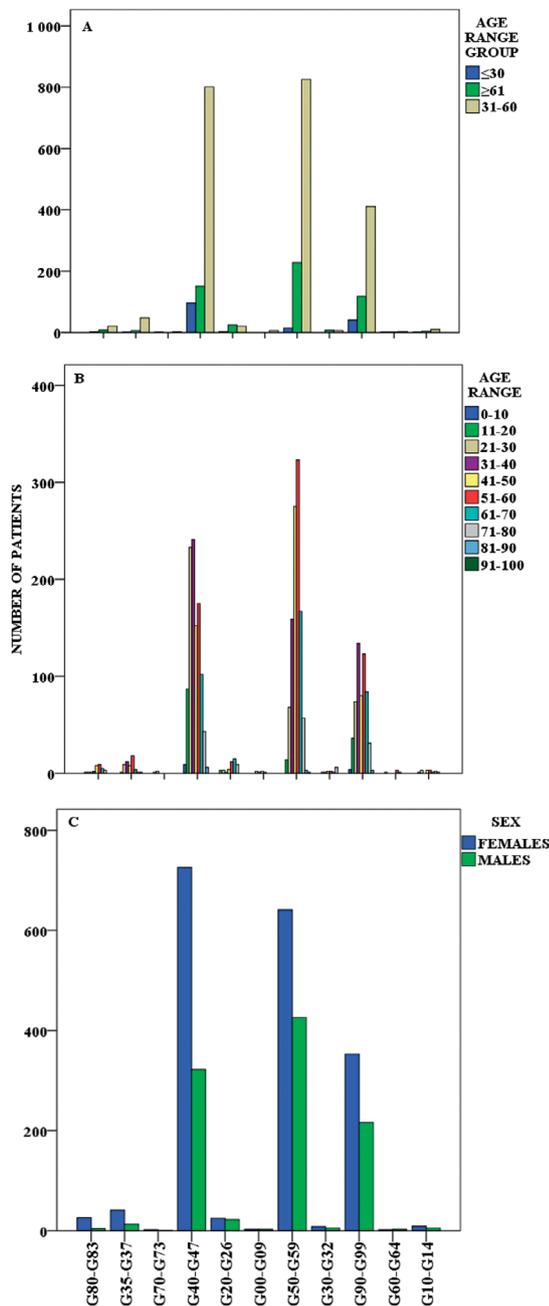
The analysis of ICD-10 general diagnoses of the S-letter-coded category showed that the most common injuries were: the knee and lower limb, shoulder and upper limb and

head injuries. The most commonly affected group was males aged 31–60 years. In females, injuries of the ankle and foot, hip and thigh, neck and wrist and hand injuries occurred more commonly than in males (Figure 1, Table 4). According to the National Collegiate Athletic Association, the most common injury sites were the ankle, knee, and lower leg, the most common injury types were muscle strains, ligament sprains, and contusions. Intrinsic risk factors of injury include (among others) age and gender. Their significance may vary depending on the sport discipline and type of injury. The literature also discusses gender differences in the frequency of some specific types of injury by hormonal, anatomical and neuromuscular factors.<sup>9</sup> In the present study, causes of injury were not available in the data source – so the linkage between physical activity or sport disciplines and demographics or injury types and locations could not be identified.

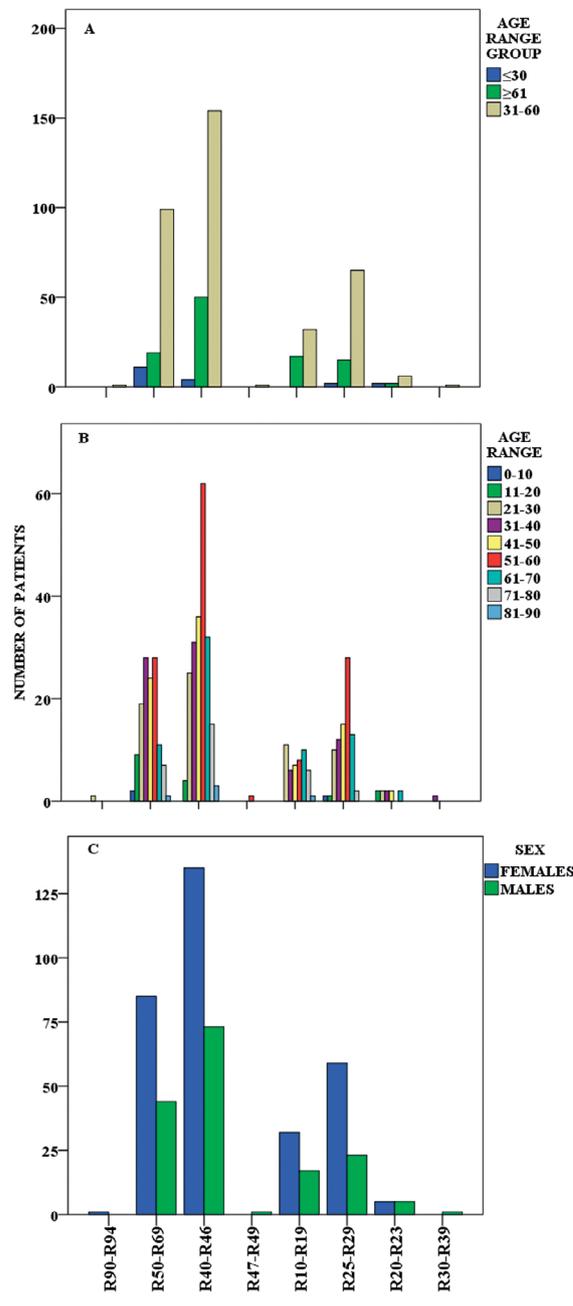
It should be stressed that the present study is based on the data obtained in only one academic teaching hospital, and over a 5-year time period. This did not generate a sufficient volume of data for detailed statistical analyses. It is recommended to continue the analyses for an additional period of 10 to 15 years in order to follow the trends in MRI-diagnosed diseases. However, despite this disadvantage, our analyses provided descriptive statistics which gives important information about the MRI-diagnosed population at the UCH.

## 6. CONCLUSIONS

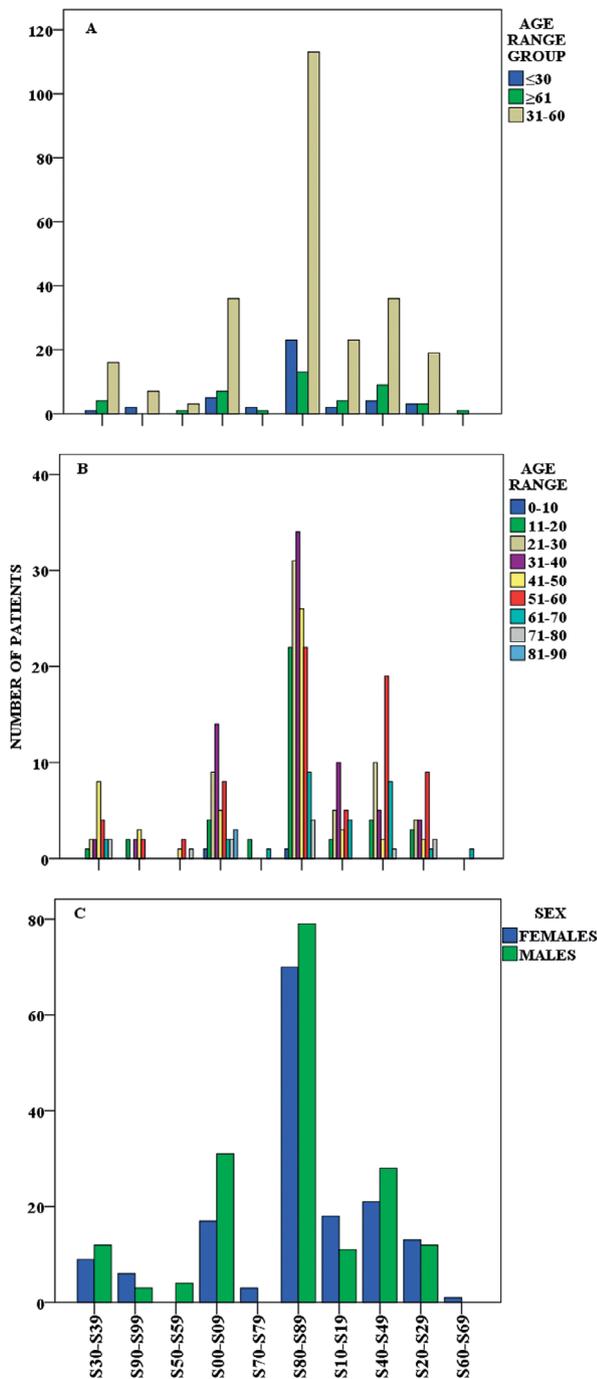
Considering the wide range of MRI use in the diagnosis of different diseases and disorders, the analysis presented here of MRI-generated data identifies the most frequent areas of applications of this technique and describes the distribution of pa-



**Figure 2.** Number of patients age range – A; 10-years intervals – B; gender – C breakdown in relation to the categories of diseases of the nervous system (G) in 5-year period of MRI utilization. Comments: G80-G83 Cerebral palsy and other paralytic syndromes, G35-G37 Demyelinating diseases of the central nervous system, G70-G73 Diseases of myoneural junction and muscle, G40-G47 Episodic and paroxysmal disorders, G20-G26 Extrapyraximal and movement disorders, G00-G09 Inflammatory diseases of the central nervous system, G50-G59 Nerve, nerve root and plexus disorders, G30-G32 Other degenerative diseases of the nervous system, G90-G99 Other disorders of the nervous system, G60-G64 Polyneuropathies and other disorders of the peripheral nervous system, G10-G14 Systemic atrophies primarily affecting the central nervous system.



**Figure 3.** Number of patients with age range – A; 10-years intervals – B; gender – C breakdown in relation to the categories of symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (R) in 5-year period of MRI utilization. Comments: R90-R94 Abnormal findings on diagnostic imaging and in function studies, without diagnosis, R50-R69 General symptoms and signs, R40-R46 Symptoms and signs involving cognition, perception, emotional state and behaviour, R47-R49 Symptoms and signs involving speech and voice, R10-R19 Symptoms and signs involving the digestive system and abdomen, R25-R29 Symptoms and signs involving the nervous and musculoskeletal systems, R20-R23 Symptoms and signs involving the skin and subcutaneous tissue R30-R39 Symptoms and signs involving the urinary system.



**Figure 4.** Number of patients with age range (A); 10-years intervals (B); gender (C) breakdown in relation to the categories of injuries and consequences of external causes (S00–S99) in 5-year period of MRI utilization. Comments: S30–S39 Injuries to the abdomen, lower back, lumbar spine and pelvis, S90–S99 Injuries to the ankle and foot, S50–S59 Injuries to the elbow and forearm, S00–S09 Injuries to the head, S70–S79 Injuries to the hip and thigh, S80–S89 Injuries to the knee and lower leg, S10–S19 Injuries to the neck, S40–S49 Injuries to the shoulder and upper arm, S20–S29 Injuries to the thorax, S60–S69 Injuries to the wrist and hand.

tients within the specific disease subgroups. The total number of MRI-diagnosed females was higher in all disease categories and age-groups with the exception of young- and middle-aged adults 31–60 years of age with externally caused injuries.

### Conflict of interest

The authors declare no conflict of interest.

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