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RESEARCH ARTICLE

The Parietal Atrophy Score on Brain Magnetic Resonance Imaging is a Reliable Visual Scale

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Abstract: ***Aims*:** The purpose of the study was to evaluate the reliability of our new visual scale for a quick atrophy assessment of parietal lobes on brain Magnetic Resonance Imaging (MRI) among different professionals. A good agreement would justify its use for differential diagnosis of neurodegenerative dementias, especially early-onset Alzheimer's Disease (AD), in clinical settings.

***Methods*:** The visual scale named the Parietal Atrophy Score (PAS) is based on a semi-quantitative assessment ranging from 0 (no atrophy) to 2 (prominent atrophy) in three parietal structures (sulcus cingularis posterior, precuneus, parietal gyri) on T1-weighted MRI coronal slices through the whole parietal lobes. We used kappa statistics to evaluate intra-rater and inter-rater agreement among four raters who independently scored parietal atrophy using PAS. Rater 1 was a neuroanatomist (JM), rater 2 was an expert in MRI acquisition and analysis (II), rater 3 was a medical student (OP) and rater 4 was a neurologist (DS) who evaluated parietal atrophy twice in a 3-month interval to assess intra-rater agreement. All raters evaluated the same 50 parietal lobes on brain MRI of 25 cognitively normal individuals with even distribution across all atrophy degrees from none to prominent according to the neurologist's rating.

***Results*:** Intra-rater agreement was almost perfect with the kappa value of 0.90. Inter-rater agreement was moderate to substantial with kappa values ranging from 0.43-0.86.

***Conclusion*:** The Parietal Atrophy Score is the reliable visual scale among raters of different professions for a quick evaluation of parietal lobes on brain MRI within 1-2 minutes. We believe it could be used as an adjunct measure in differential diagnosis of dementias, especially early-onset AD.

Keywords: Parietal Atrophy Score, reliability, visual scale, brain magnetic resonance imaging, Alzheimer's disease, dementia.

1. INTRODUCTION

Brain Magnetic Resonance Imaging (MRI) is used to support the diagnosis of Alzheimer's Disease (AD) [1-4]. Non-invasiveness and good availability are the main advantages which make brain MRI a suitable technique for routine clinical practice. Some brain structures exhibit atrophy earlier than the others during the progression of AD [5]. These changes are well evaluated on brain MRI [6]. Tissue loss in mediotemporal area is typical for late-onset AD (patients older than 65 years) [7-13]. Parietal atrophy with a relatively preserved structure of a mediotemporal region is more often found in patients with early-onset AD (individuals younger than 65 years) [14-17].

Atrophy of these brain structures can be evaluated on MRI by quantitative techniques using manual and automatic segmentation [18-21]. Objective results and accuracy of such measurements are the main advantages of these approaches. However, these techniques are often time-consuming or require specialized software and skills. Visual scales represent a simple option to evaluate brain atrophy quickly and thus are more suitable for clinical practice [22-24]. Their main disadvantage is possible variability among individual scoring of different raters. A good inter-rater agreement is one of the essential features of visual scale quality. This reliability can be evaluated using Cohen's kappa coefficient [25, 26].

The Koedam visual scale for assessing parietal and partly occipital atrophy is used mainly in research studies [22]. This approach is based on rating of four structures on coronal, sagittal and axial T1-weighted MRI slices [27]. The Koedam scale has good reliability, but is not widely used in routine clinical practice [22]. We developed a brief and simple visual scale named the Parietal Atrophy Score (PAS)

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for assessing parietal lobe structure in our previous reports [28, 29]. Reliability of the PAS was evaluated in this study.

2. METHODS

2.1. Visual Scale Named the Parietal Atrophy Score (PAS)

Our PAS visual scale is based on semi-quantitative scoring of three parietal structures through the whole range of parietal lobes: Precuneus, sulcus cingularis posterior and parietal gyri. Atrophy of the structures was evaluated visually on multiple T1-weighted coronary slices from the beginning of cerebellar hemispheres ventrally to the transition between parietal and occipital lobe dorsally. Each of these areas was ranked as follows: 0-a normal size without atrophy, 1-a borderline finding or 2-a prominent atrophy. Three structures and their three grades of atrophy are shown in Fig. (**1**). The ratings of three structures were summarized into one parietal atrophy score for each hemisphere: PAS 0-a normal size without atrophy, PAS 1-a borderline finding or PAS 2-a prominent atrophy of the parietal lobe (Fig. **1**). The final score for the entire brain was derived from left and right parietal atrophy scores. The total score (PASglob.) for the whole parietal region of both sides can be 0-a normal size without atrophy, 1-a borderline finding, 2-a prominent atrophy of just one parietal lobe, 3-a prominent atrophy of both sides. The scoring criteria for determining the PAS and PASglob. are summarized in Appendix and also described in our previous Czech reports [28, 29].

2.2. MRI Data Pre-processing

Three-dimensional MR images of T1W-MPRAGE (T1 weighted Magnetization Prepared Rapid Acquisition Gradient Echo) in the sagittal plane on the 3T Siemens Magnetom Trio were used with the following parameters: Voxel size: $0.85 \times 0.85 \times 0.85$ mm^3, number of layers: 224, repetition time (TR)/echo time (TE): 2000/4.73 ms, TI (inverse time): 800 ms, tilting angle 10° and Time of Measurement (TA): 10 min. Evaluation was performed on MPR reconstructions in the coronal plane with a 0.85 mm slice thickness.

2.3. Participants

50 parietal lobes on brain MRI of 25 cognitively normal individuals with Mini-Mental State Examination 29±1 points, age range 48-76 years, 72% female gender were selected from our previous report [28] so that all four grades of PASglob. (0-3) were equally represented in this group: 25% PASglob. 0-a normal size without atrophy, 25% PASglob. 1-a borderline finding, 25% PASglob. 2-a prominent atrophy of just one parietal lobe, 25% PASglob. 3-a prominent atrophy of both sides.

2.4. Raters' Characteristics

Four raters with different professions and experience in MRI evaluated selected MRI images using the PAS. Rater 1 (JM) is a neuroanatomist with 10-year experience in evaluating brain structures on MRI [11, 18, 30]. She was explained PAS scoring in person in a 15-minute training. Rater 2 (II) is an expert in brain MRI acquisition and analysis with 15-year experience [31]. He learned the scoring system from our first published study about the PAS [28]. Rater 3 (OP) is a medical student at Charles University in Prague with no previous MRI experience. First, she learned scoring guidelines from our first study about the PAS, then she was trained in brain MRI with a focus on the evaluation of parietal atrophy using the PAS during 20-minute session. Rater 4 (DS) is a neurologist developing the PAS with 3-year experience in brain MRI in cognitive disorders. Rater 4 evaluated all 50 parietal lobes on brain MRI twice in a

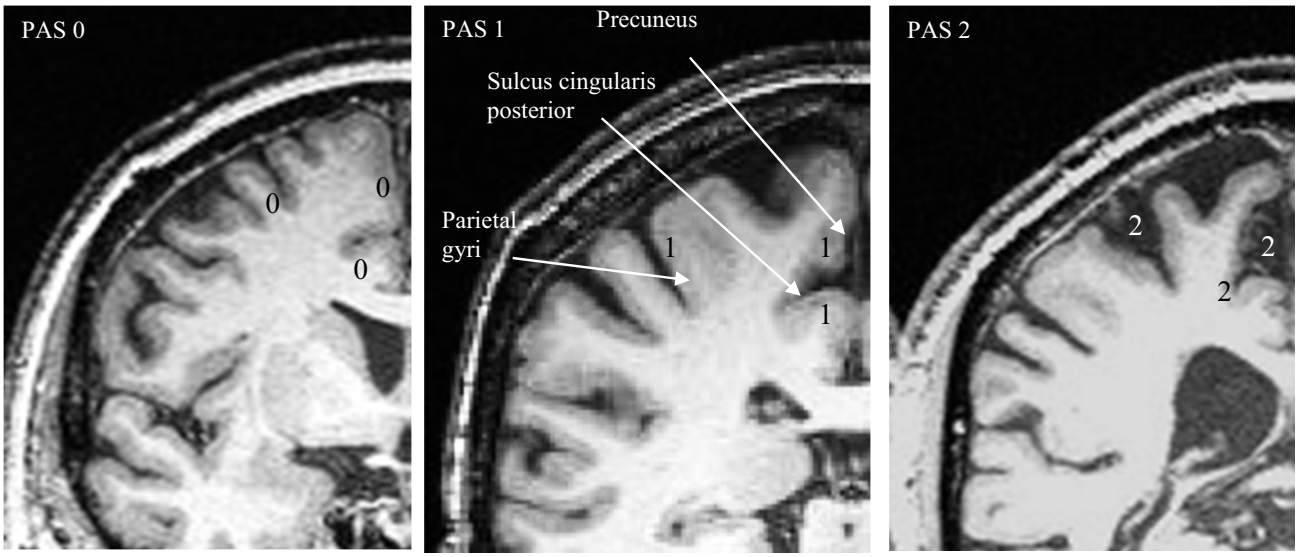

Fig. (1). Three grades of Parietal Atrophy Score in the right lobe: PAS 0 - a normal size without atrophy, PAS 1 - a borderline finding and PAS 2 - a prominent atrophy of parietal lobe. Three parietal lobe structures and their atrophy degrees (0 - 2) are visualized: Parietal gyri, sulcus cingularis posterior and precuneus. Examples of brain MRI images were taken from individuals who had the identical PAS by all four raters. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

3-month interval. Raters performed ratings independently of each other.

2.5. Statistical Analysis

We evaluated the reliability of our PAS visual scale using kappa statistics, which is often applied for testing agreement of ordinal data among different raters [25, 26]. Degree of agreement (weighted-kappa value) was defined according to Landis and Koch, who characterized values<0 as indicating no agreement and 0-0.20 as slight, 0.21-0.40 as fair, 0.41-0.60 as moderate, 0.61-0.80 as substantial, and 0.81-1 as almost perfect agreement [25]. Kappa values were calculated in MedCalc software. We also determined the percentage of absolute agreement in the PAS among raters. The absolute agreement means that both parietal atrophy scores from two raters were identical.

3. RESULTS

Intra-rater agreement of the neurologist was almost perfect with weighted-kappa value 0.9 in both hemispheres.

Weighted-kappa values for inter-rater agreement are summarized in Table **1**. Percentages of absolute agreement of four raters are shown in Table **2**.

4. DISCUSSION

The PAS visual scale has almost perfect intra-rater and moderate to substantial inter-rater reliability despite professional diversity, different experience and training of the raters. The good agreement of a visual scale is one of the most important features of good quality, which makes this semi-quantitative approach more objective [22]. Surprisingly, the best agreement was between the neurologist (DS) and the medical student (OP) with no previous MRI experience. On the other hand, only OP studied PAS scoring from our first publication and was also explained the PAS in a 20-minute training. The effect of learning seems to be more important than professional experience. However, learning scoring guideline alone can still provide substantial agreement in a PAS assessment. Thus, this rating can be transferable to other users even without the personal explanation.

Our PAS is an easy visual scale to quantify parietal atrophy on brain MRI. This approach does not require specialized software and nothing more than vision and basic knowledge about brain MRI structures are needed. Even a student of medicine with no previous MRI experience was able to use PAS reliably after short training. A further advantage is also rating of atrophy only in the coronal plane, similarly to medial temporal lobe atrophy score [32]. It can save time when both techniques are simultaneously performed. The PAS visual scale requires a short assessment time (1-2 minutes) compared to the other semi-quantitative and also quantitative techniques for evaluating parietal atrophy.

The Koedam visual scale is a reliable approach used in research [22]. It has almost perfect intra-rater agreement with weighted-kappa value ranging from 0.92-0.93 and substantial inter-rater agreement with kappa value from 0.62-0.84 according to the original study [27]. Our PAS has comparable reliability to the Koedam scale. In addition, a high correlation between these two scales was demonstrated in both hemispheres in our previous study (the Spearman's correlation coefficient on the left $r = 0.75$; $p = 0.00001$, on the right $r = 0.63$; $p = 0.0008$) [28]. Unlike Koedam scale, the rating of our PAS visual scale is simpler, faster and based on cor-

Table 1. Inter-rater agreement (expressed as weighted-kappa value) in the right and left parietal lobe among four raters using the Parietal Atrophy Score (PAS) to assess parietal size on brain magnetic resonance imaging.

Weighted-kappa Value Right / Left			
Rater	neurologist	medical student	MRI analyst
neuroanatomist	0.75 / 0.62	0.58 / 0.58	0.43 / 0.51
MRI analyst	0.60 / 0.71	0.44 / 0.67	-
medical student	0.82 / 0.86	-	-

Table 2. Percentages of absolute agreement among four raters using the Parietal Atrophy Score (PAS) to assess parietal size on brain magnetic resonance imaging.

Percentage of Absolute Agreement in PAS Right / Left			
Rater	neurologist	medical student	MRI analyst
neuroanatomist	80% / 68%	64% / 64%	60% / 64%
MRI analyst	72% / 80%	60% / 76%	-
medical student	84% / 88%	-	-

onal slices only. Therefore, it can be more suitable for routine clinical practice.

One of the limitations of our study could be smaller sample size comparing to previously mentioned Koedam study where reliability of the visual scale was also assessed [27]. On the other hand, we are convinced that 50 PAS evaluations (PAS was assessed on both sides separately on 25 brain MRI) by each rater should be sufficient for the relevant determination of inter- and intra-rater agreement [33]. PAS is a visual scale dependent on the rater's estimation which may not be always be quite accurate. Unfortunately, the parietal lobe is very complex. Thus it is very difficult to create automated software for assessment of this brain region. Moreover, it would be problematic to use it in routine clinical practice.

We believe that the PAS visual scale has a potential to become one of the supportive tools for the diagnosis of AD. This approach could be useful for radiologists and also neurologists and other professionals specializing in neurodegenerative dementias. Differential diagnosis of early-onset AD with a typical pattern of parietal atrophy and other dementias with preserved parietal tissue (mainly frontotemporal lobar degeneration) could be promising use of the PAS, but it needs to be verified in future studies.

CONCLUSION

The Parietal Atrophy Score is the reliable, brief (1-2 minutes) and simple visual scale to assess structure of the parietal lobes on brain MRI. This approach could have a potential to support the diagnosis of early-onset AD in routine clinical practice.

LIST OF ABBREVIATIONS

MRI = Magnetic Resonance Imaging

AD = Alzheimer's Disease

PAS = Parietal Atrophy Score

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Ethical Committees of the Faculty Hospital Královské Vinohrady, Prague, Czech Republic and Prague Psychiatric centre, now National Institute of Mental Health, Klecany, Czech Republic (under No 87/11 and 81/2006).

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All humans research procedures followed were in accordance with the standards set forth in the Declaration of Helsinki principles of 1975, as revised in 2008 (http://www.wma.net/en/20activities/10ethics/10helsinki/).

CONSENT FOR PUBLICATION

Authors complied with the guidelines of the International Committee of Medical Journal Editors ("http://www.icmje.org" www.icmje.org) with regard to the patient's consent for research or participation in a study. Patients' names, initials, or hospital numbers were not mentioned anywhere in the manuscript (including figures).

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, [AB], upon reasonable request.

FUNDING

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

APPENDIX

PARIETAL ATROPHY SCORE (PAS) ON BRAIN MRI

1) All coronal slices need to be assessed from the anterior part of cerebellar hemispheres ventrally to the border between parietal and occipital lobe dorsally.

2) Focus on three structures: 1) sulcus cingularis posterior (most important), 2) precuneus, 3) parietal gyri (see Fig. **2**).

3) Score each of these parietal structures on one side with degree 0 as a normal finding without atrophy (Fig. **1**), or with 1 as a borderline finding (Fig. **2**), or with 2 as a prominent atrophy (Fig. **3**).

4) Combine these three subscores into one hemispheral Parietal Atrophy Score (PAS) according to the rules in Table **1** bellow on the left.

5) Finally, combine two hemispheral PAS into one total score (PAS glob.) for the whole brain according to the rules in Table **2** below on the right.

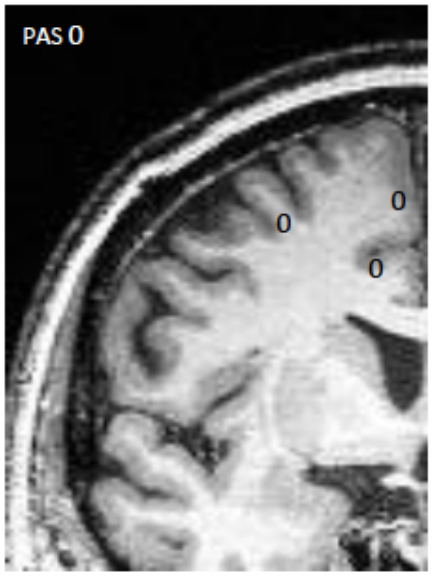

Fig. (1). Normal size of parietal lobe without atrophy

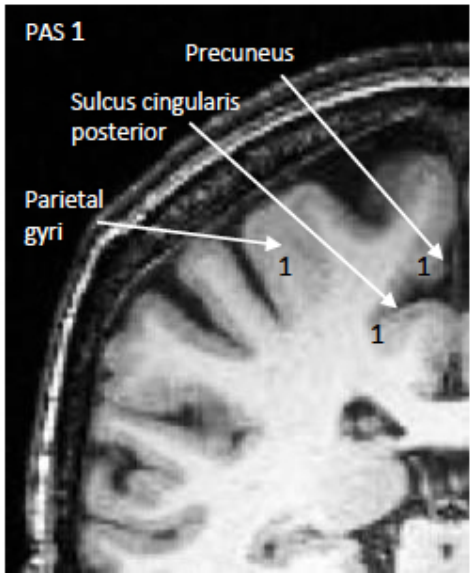

Fig. (2). Borderline finding

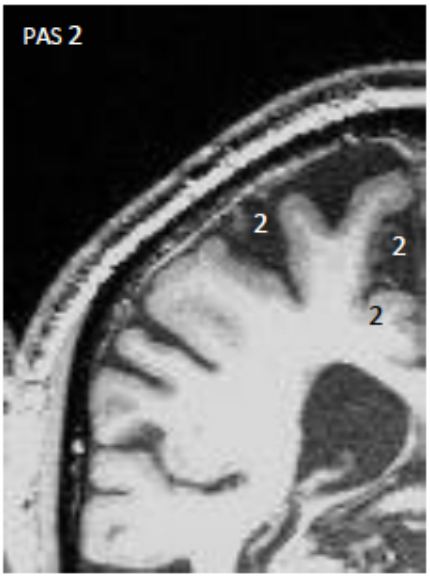

Fig. (3). Prominent atrophy of parietal lobe

Table 1. Criteria for determining of the PAS right or left.

Parietal Atrophy Score (PAS) on the right or left	Criteria
0 a normal size of parietal lobe without atrophy	the total sum of atrophy degrees of three evaluated structures is 0 or 1
1 a borderline finding	the criteria for rating PAS 0 or 2 are not met
2 a prominent atrophy of the lobe	a) precuneus is ranked 2 or b) parietal gyri are ranked 2 or c) sulcus cingularis posterior is ranked 2 and at least one other structure is ranked 1

Table 2. Criteria for determining of the PAS glob.

Parietal Atrophy Score (PAS) on the right / left	Total score (PASglob.)
0 / 0	0 a normal size without atrophy
0 / 1 or 1 / 0	0 a normal size without atrophy
1 / 1	1 a borderline finding
2 / 0 or 0 / 2	2 a prominent atrophy of one parietal lobe
2 / 1 or 1 / 2	2 a prominent atrophy of one parietal lobe
2 / 2	3 a prominent atrophy of both lobes

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