

Might it be possible to assess rigidity in PD patients remotely?

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Word Count: 554

Running Title: Video-based assessment of Rigidity in Parkinson's disease

Key words: Rigidity, Parkinson's disease, Video Assessment, Remote Assessment, Unified Parkinson's disease Rating Scale

Rigidity is present in up to 89% of Parkinson's disease patients [1]. It refers to uniform and persistent resistance to passive movement at a joint, due to increased resting muscle tone [2]. The MDS-UPDRS part 3 is the gold-standard assessment of rigidity. This involves a clinician flexing and extending a patient's relaxed joint, assessing both upper (wrist, elbow, neck) and lower extremities (knee and ankle), as well as instructing the patient to perform voluntary movements in the contralateral limb, to accentuate rigidity. The need for hands-on assessment to detect and quantify rigidity makes implementation of remote video assessment difficult. Rigidity is therefore usually omitted from video ratings [3], thus a patient's symptomatology may not be completely represented via video assessment.

We evaluated data collected as part of the standard clinical care of PD patients being assessed for Deep Brain Stimulation (DBS). Three experienced DBS specialist nurses performed a hands-on MDS-UPDRS rigidity assessment on 39 patients with Parkinson's disease, in the OFF and ON medication conditions. This assessment was video-recorded with patient's consent. The nurses re-rated the same videos of these patient's OFF and ON rigidity assessments between 6 months-2 years later. It was found that nurse's video scores of rigidity had excellent agreement with their own previous in-person scores (ICC=0.97, CI=0.92-0.99).

To control for potential bias that may arise from nurses remembering patients that they had previously rated, 2 secondary experienced raters (Rater 1 and Rater 2) who had never seen the patients before, rated videos of a total of 51 patients who had had a rigidity assessment performed by a nurse, and their scores were compared to scores obtained from the hands on assessment. We found that each rater's video scores of rigidity also had excellent agreement with previous in-person rigidity scores (ICC=0.96 CI=0.95-0.97). Assessors were asked to describe potential visual cues that guided their rigidity scores when watching videos of a previous clinician performing the assessment (see Table).

Table. *Potential visual cues used among raters when rating rigidity from videos of a previous clinician performing a rigidity assessment on a patient*

MDS-UPDRS Score	MDS-UPDRS Description	Visual Cues
0: Normal	No rigidity.	<ol style="list-style-type: none"> 1. Can see clinician moving patient's limb with ease- floppy /limb appears loose/ fluidity of movement 2. Full range of movement clearly observed
1: Slight	Rigidity only detected with activation manoeuvre.	<ol style="list-style-type: none"> 1. Resistance/ stiffness/less fluidity/slowness observed when clinician moves limb, only when patient performs an activation manoeuvre
2: Mild	Rigidity detected without the activation manoeuvre, but full range of motion is easily achieved.	<ol style="list-style-type: none"> 1. Slowness/slight stiffness/less fluidity/slight resistance/locking visible when clinician moves limb through movement trajectory 2. No activation manoeuvre needed to observe above 3. Full range of movement achieved with little observable effort from the clinician
3: Moderate	Rigidity detected without the activation manoeuvre; full range of motion is achieved with effort.	<ol style="list-style-type: none"> 1. Clinician moves limb significantly slower/ marked resistance/ very stiff/significant locking 2. No activation manoeuvre needed to observe above 3. Full range of movement achieved with observable effort from the clinician
4: Severe	Rigidity detected without the activation manoeuvre and full range of motion not achieved.	<ol style="list-style-type: none"> 1. Clinician is clearly unable to move limb to full range 2. No activation manoeuvre needed to observe above

MDS-UPDRS, Movement Disorder Society Revised Unified Parkinson's disease Rating Scale

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50 These data suggest that it is possible to rate rigidity via videos, with excellent inter and intra rater
51 agreement, if a clinician performed the original rigidity examination. The proposed visual cues guide
52 above may be used to support rating rigidity via videos, but this needs further validation. This has
53 implications for clinical trials, because it might allow the use of videos (performed previously by a
54 nurse/clinician) for blinded rating of the rigidity section of the MDS-UPDRS part 3.

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56 Whether this may be useful for clinical care adds further complexity. Routine remote video
57 assessments will not have the presence of a qualified clinician to perform the hands-on rigidity
58 measure. In addition, the visual cues described here may not be present during examinations
59 performed by clinicians from other centres with different backgrounds in training and, the visual cues
60 described here were generated in an unblinded rigidity assessment and may not be applicable to
61 blinded assessments by an additional rater. More data are needed with research methods addressing
62 the above key points to further the findings presented in this primary investigation. Further
63 exploration may also reveal whether the patient's spouse/carer could be instructed to perform the
64 passive movements in the home environment, to allow a remote experienced observer to score
65 rigidity through videos. This might explore further which visual cues most reliably indicate rigidity,
66 which may be exploited in such assessments or even by machine learning approaches.

67 **Acknowledgements:**

68 **Author Roles:**

- 69 1. Research project: A. Conception, B. Organization, C. Execution;
- 70 2. Statistical Analysis: A. Design, B. Execution, C. Review and Critique;
- 71 3. Manuscript Preparation: A. Writing of the first draft, B. Review and Critique.

72 K.G.S.: 1A, 1B, 1C, 2A, 2B, 2C, 3A

73 C.G.: 1A, 1B, 1C, 2A, 3A

74 T.F.: 1A, 1B, 2C, 3B

37 C.M.: 1C

38 M.S.: 1C

39 J.C.: 1C

01 **Disclosures:**

02 **Ethical Compliance Statement**

03 All movement disorder clinic patients whose videos were analysed provided written consent for use of
04 videos for medical research. We confirm that we have read the Journal's position on issues involved
05 in ethical publication and affirm that this work is consistent with those guidelines.

06 **Funding Sources and Conflict of Interest**

07 There were no funding sources for this work. The authors declare that there are no conflicts of
08 interest relevant to this work.

09 **Financial Disclosures for the Previous 12 Months**

00 TF has received grants from National Institute of Health Research, Michael J Fox Foundation, John
01 Black Charitable Foundation, Cure Parkinson's Trust, Innovate UK, Van Andel Research Institute and
02 Defeat MSA. He has served on Advisory Boards for Peptron, Voyager Therapeutics, Handl therapeutics,
03 Living Cell Technologies, Bial & Profile Pharma. He has received honoraria for talks sponsored by Bial,
04 Profile Pharma, Boston Scientific.

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