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ORIGINAL ARTICLE

Pneumophonic Coordination Impairments in Parkinsonian Dysarthria: Importance of Aerodynamic Parameters Measurements

Les troubles de la Coordination Pneumophonique dans la Dysarthrie Parkinsonienne: Importance de la Mesure des Paramètres Aérodynamiques

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ABSTRACT

BACKGROUND: **Among Parkinsonian axial signs, dysarthria represents an important disabling symptom able to lead towards a significant reduction of oral communication. Several methods of dysarthria assessment have been used but aerodynamic evaluation is rare in the literature.**

OBJECTIVE: **To highlightthe importance of aerodynamic parameters measurements in assessment of parkinsonian dysarthria.**

PATIENTS AND METHODS: **Using a dedicated system (EVA2), 24 parkinsonian patients were recorded after withdrawal of L-dopa for at least 12 h (condition called OFF DOPA) in order to evaluate intra-oral pressure (IOP), mean oral air flow (MOAF) and laryngeal resistance (LR) on six /p/ during realization of the sentence "Papa ne m'a pas parle´ de beau-papa" ("Daddy did not speak to me about daddy-in-law") which corresponds to a breath group. 50 control subjects were recorded in parallel in order to define reference measurements.**

RESULTS: **It appeared that there is in Parkinson's disease aerodynamic impairments which were evidenced by the fall in IOP and that of MOAF in patients compared with control subjects. The difference between the two groups was statistically significant. In addition a greater instability of LR in patients compared with control subjects was also noted.**

CONCLUSION:**Our results show that measurements of aerodynamics parameters, by reflecting the dysfunction induced by disease, may well be relevant factors in parkinsonian dysarthria evaluation. WAJM 2012; 31(2): 129–134.**

Keywords: **Intra-oral pressure, Oral airflow, Laryngeal resistance, Parkinson's disease, Dysarthria, Pneumophonic coordination, Aerodynamic evaluation.**

RÉSUMÉ

CONTEXTE: Parmi les signes axiaux de la maladie de Parkinson, la dysarthrie représente un symptôme handicapant car pouvant aboutir à une réduction significative de la communication orale. Plusieurs méthodes d'évaluation de cette dysarthrie ont été rapportées dans la littérature, mais l'évaluation aérodynamique demeure plus rare.

OBJECTIF: Montrer l'importance de la mesure des paramètres aérodynamiques dans l'évaluation de la dysarthrie parkinsonienne.

PATIENTS ET METHODE: En utilisant un système approprié d'évaluation vocale (EVA 2), 24 patients ont été enregistrés après sevrage en L-dopa d'au moins 12h (condition dite OFF Dopa) afin de mesurer la pression intra-orale (PIO), le débit d'air oral moyen (DAOM) et la résistance laryngée sur les six /p/ de la phrase "Papa ne m'a pas parle´ de beau-papa". 50 sujets-contrôles ont été enregistrés parallèlement.

RESULTATS: Il est apparu qu'il y a dans la maladie de Parkinson des troubles de la coordination pneumophonique objectivés par une baisse de la PIO et du DAOM chez parkinsoniens comparativement aux sujets-contrôle. La différence entre les deux groupes était statistiquement significative. En outre, une plus grande instabilité de la résistance laryngée était notée chez les patients, comparativement aux sujets-contrôles.

CONCLUSION: Nos résultats montrent que la mesure des paramètres aérodynamiques, en objectivant les troubles de la coordination pneumophonique induits par la maladie, peut être pertinente dans l'évaluation de la dysarthrie parkinsonienne. **WAJM 2012; 31(2): 129–134.**

Mots-clés: Pression intra-orale, Débit d'air oral, Résistance laryngée, Maladie de Parkinson, Dysarthrie, Coordination pneumophonique, Evaluation aérodynamique.

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INTRODUCTION

Parkinsonian dysarthria is generally known under the name of hypokinetic dysarthria. Dysarthria, according to Darley *et al,*[1] is characterized by all speech disorders related to disturbances of muscular control of the speech organs, whose origin is a central or peripheral nervous system injury. So we must understand by dysarthria all failures related to either different levels of speech production (respiratory, phonatory, articulatory and prosodic same). Parkinsonian dysarthria, meanwhile, is mainly based on rigidity and hypokinesia. That's why it is considered as « hypokinetic».[2, 3] This term refers not only to reductionof articulatory movementsbut also to decreasing of speech prosody modulation described as monotonic.[4] Parkinsonian dysarthria arises, like other signs of Parkinson's disease, the depletion of dopamine in charge of phonatory incompetence by muscular hypokinesia. It is a major handicap factor that may compromise in long-term oral communication of the patient, as worsening over the course of the disease, responding less well to treatment and thereby posing additional difficulties in support. So we thought to better assess this dysarthria in order to gain a better understanding and improve management. This assessment can be done by perceptual analysis. She could also be done by various instrumental methods (acoustic and physiological) focusing on one of the speech production levels mentioned above. Such studies are numerous in literature. What is more rare in literature is assessment of parkinsonian dysarthria in study combined several levels as might allow, for example, the dual approach appealing to physiology of speech production with firstly an aerodynamic component relatedto pneumophonic coordination (respiratory and phonatory levels)and, secondly, an acoustic component in relation to phonoarticulatory co-ordination (phonatory and articulatory levels). Through this study we want show that it is possible to assess appropriately parkinsonian dysarthria by using aerodynamic parameters that combine respiratory and phonatory levels.

SUBJECTS, MATERIALS AND METHODS

Patients and Control Subjects

The study included 24 subjects with PD who had an average age of 59 years (SD = 5.65) with a mean duration of disease about 9, 9 years (SD = 3.27). Patients were selected through a specialized consultation of Neurology. Patients were followed at the Department of Neurology in Aix-en-Provence Hospital Center. Patients were recorded after withdrawal of L-dopa for at least 12 h (condition called OFF DOPA).

50 age-matched healthy subjects were selected to serve as control.They had an average age of 61 years (SD = 10, 5).Patients and control subjects were included in the study after signing an informed consent.

Equipment and Measurement Technique

Equipment

We used in this study the vocal evaluation system EVA 2 developed by the Laboratory of Speech and Language and sold by SQ-Lab society. EVA 2 operates as a workstation PC in the Windows environment with different software applications dedicated to acoustic and aerodynamic analysis of speech production. The recording device includes an acoustic channel and two aerodynamic channels: one for measurement of mean oral airflow (MOAF), the other for the IOP measurement. It is thus possible to measure IOP during holding of a voiceless plosive such as /p/.

Technique

The measurement technique derives from the general theory of fluids dynamic applied to the airway.According to this theory it is possible by adjustments of valves to estimate pressure-flow upstream from the direct measurement of pressure-flow downstream of the target site. The adjustments of valves in question occur naturally during the pronunciation of certain sounds. For example, during production of the consonant / p / the lips are closed while the glottis is open. In contrary during pronunciation of the vowel / a / the lips are open while the glottis is closed. The different conformation of these examples of valves located on the airway (glottis and lips) has a physical impact on the pressure and flow dynamics prevailing inside airway. So during the realization of a voiceless plosive (/ p /), there is a momentary equilibration of intra-oral and subglottic pressures. This equilibration allows indirect assessment of SGP (upstream) via the direct measurement of IOP (downstream). The momentary equilibration of subglottic and intra-oral pressures occurs when holding the voiceless plosive because at this moment there is no phonation, the lips are closed and the glottis is open. Thus the peak pressure generated by holding a voiceless plosive may be considered as a "snapshot" of the subglottic pressure immediately preceding phonation. Similarly during the realization of the vowel (/ a /) following a voiceless plosive (lips are open and glottis is closed), it is possible to consider the oral airflow as a snapshot of translaryngeal airflow because of continuity of flow through the upper airway when the mouth is open. Once we got the two parameters, it suffices to calculate the ratio of intra-oral pressure on the oral airflow to determine the laryngeal resistance[5, 6] (See Figure 1).

Measurements were performed while the subject produced at a constant rate the phrase "Papa ne m'a pas parlé de beau-papa" (Daddy did not speak to me about daddy-in-law). During this production, oral mouth was firmly against the underside of the face to minimise air leakage. Taking IOP is performed using a disposable suction catheter approximately 4 mm.The probe was placed between the incisors and should not be crushed between the teeth or be obstructed by saliva.

Statistical Analysis

Statistical comparisons between groups (CTRL vs. OFF DOPA) were conducted on the basis of a linear mixed model (software "R" version 2.6.2, http://www.r-project.org). This model emerged as best suited to the analysis of grouped data. Indeed, the repeated measurements, longitudinal studies are data that are presenting a group structure. And in our case, a single individual is undergoing multiple measures, and structured data in this way no longer meet one of the fundamental prerequisites for the validity of a classical linear model, namely the independence of measures. We set our statistical comparisons as follows: measurements of aerodynamic parameters (IOP, MOAF and LR) accounted for the numerical factor of the model, the group (CTRL, OFF DOPA), the position of the consonant / p / in the sentence produced (P1, P2, P3, P4, P5, P6) and the subject (patients, controls) were the three factors model variability. A value of p less than 0.05 was accepted as statistical significance.

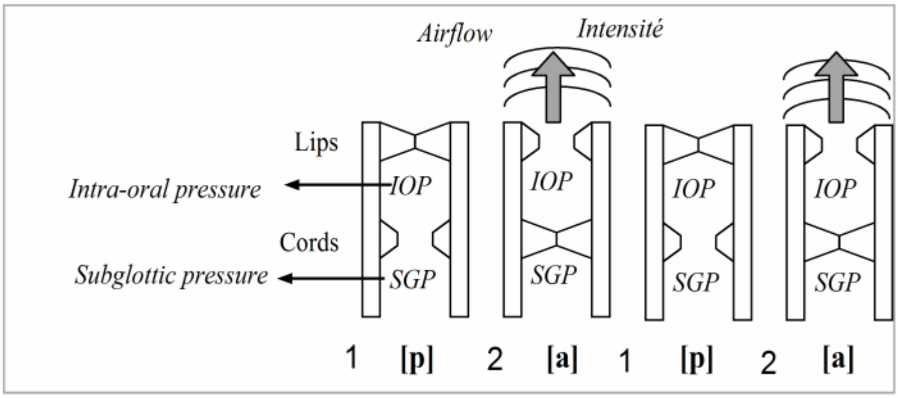

Fig. 1. Evaluation of the Subglottic Pressure.

Intraoral pressure (IOP) is equivalent to the subglottic pressure (PSG) during the labial occlusion of phoneme "p". Subglottic pressure is estimated indirectly by "Interrupted Airway Method" (Smitheran & Hixon, 1981), method validated notably by Demolin *et al.* (1997).

RESULTS

Intra-oral Pressure

We noted, as regards the IOP, a statistically significant decrease in patients compared to controls (p = 0.0001) (See Figure 2).

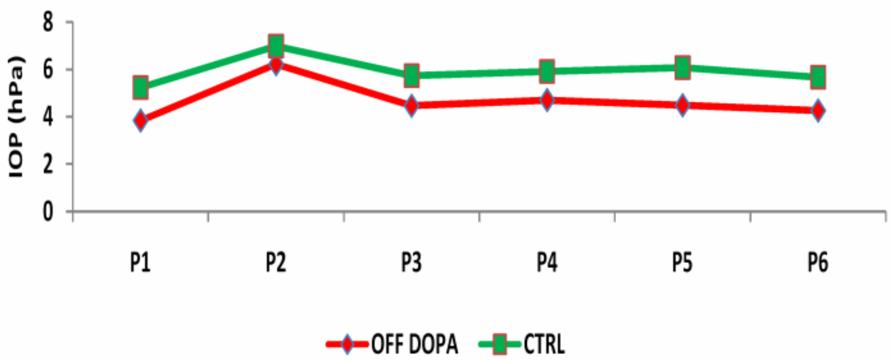

Fig. 2: Curve of the Intra-oral Pressure (I0P) in Control Subjects (CTRL) and OFF DOPA Patients at Six Measurement Points

Mean Oral Airfow

Concerning mean oral airflow (MOAF) the curve of mean values at six points of measurement in control subjects (CTRL) and OFF DOPA patients showed an convergent aspect at extremities so that P1 and P6 while at the other measurement points (P2 to P5), the two curves were clearly separated: that of control subjects remain above that of OFF DOPA patients (seeFigure 3). The comparison between the two groups was statistically significant (p = 0.001).

Laryngeal Resistance

Finally for the LR, the graphical representation of mean values at six points of measurement in control subjects (CTRL) and OFF DOPA patients showed on one hand a more linear overall appearance of the control-subjects 'curve, on the other hand, a curve of OFF Dopa patients above that of control subjects from P1 to P4 and then, below, beyond P4. In addition standard deviations were significantly larger in OFF DOPA patients than in control subjects (See Figure 4). The comparison between the two groups was statistically significant (p <0.05).

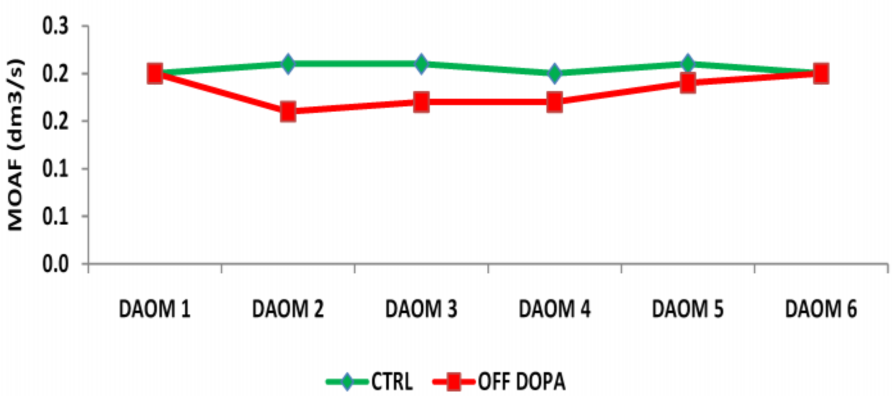

Fig. 3: Curve of Mean Oral Airflow (MOAF) in Control Subjects (CTRL) and OFF DOPA Patients at Six Measurement Points.

NB: *DAOM is the french abbreviation of mean oral air flow (MOAF)*

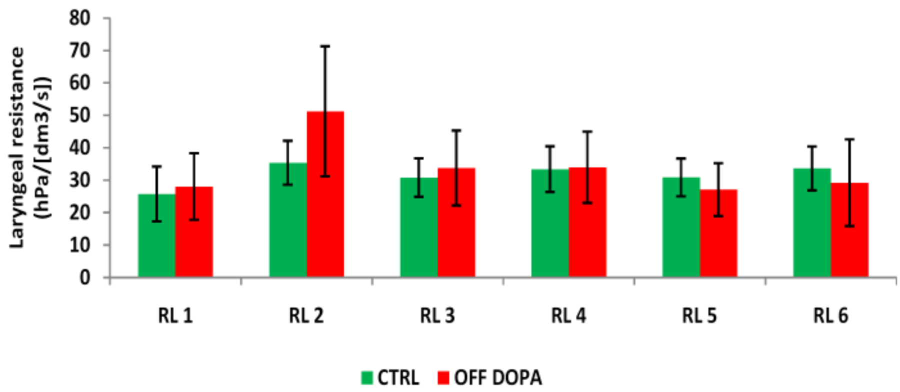

Fig.5: Histogram of mean values of Laryngeal Resistance (LR) in Control Subjects (CTRL) and Patients OFF DOPA at six measurement points, with Standard Deviations. The Histogram allows to better see the Standard Deviations significantly larger in patients.

NB: RL is the french abbreviation of laryngeal resistance (LR)

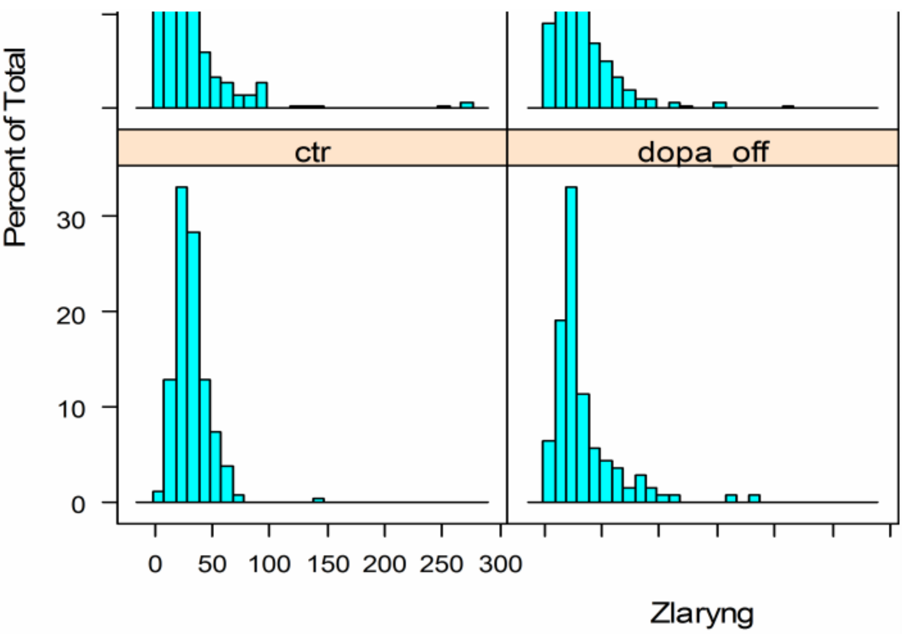

Fig. 6: Histogram of the Distribution of values of Laryngeal Resistance (Zlaryng).

There is a fairly symmetrical distribution for control subjects, while values distributions are more skewed in OFF DOPA patients.

DISCUSSION

This new study that examined 24 patients and 50 control subjects confirms the decrease of IOP on all six measurement points of the sentence when comparing patients with control subjects.The decrease of IOP, found in a previous study,[7] seems to confirm definitively the alteration of this parameter in parkinsonian dysarthria. The decrease of IOP in patients is due to dopamine deficiency inherent in PD. Dopamine deficiency induces a dysfunction of the respiratory muscles that is partly responsible for the dysarthria.[8] Indeed there are, within overall poor control of expiratory airflow, an alteration of the air quantity needed for the vibration of vocal cords.[9,10] However, the SGP is the result of a surge in air column by the pressure of lung with laryngeal resistance.[11,12] In the particular context of this study, when measuring IOP via the GSP, the glottis is open, at that time so it's a pressure gradient which is measured and not a static value. This gradient is the result of coordinated action between the respiratory muscles and laryngeal floor, so it indicates pneumophonic coordination quality. In PD, the fall in pulmonary pressure associated with hypokinetic movements of laryngeal muscles induced an alteration of the PSG. So we have shown in this study that it is possible to consider the GSP, or IOP, as a strong indicator of Parkinsonian dysarthria in general and its pneumophonic side particularly. We confirm at the same the results already published in a preliminary study.[7] Therefore, the measurement of IOP may allow together, comparing OFF DOPA patients and control subjects, assessment of the disease impact on speech disorders and contribution to evaluation of somes therapies such as L-dopa and subthalamic nucleus stimulation on parkinsonian dysarthria. As a reminder in our study,[7] STN stimulation improves IOP significantly in the initial part of the expiratory phase.

Regarding the mean oral airflow (MOAF), no difference was found between patients in OFF DOPA and control subjects at the first and last measurement point (P1 and P6). That means patients and control subjects would develop the same speed to start and finish the sentence «Papa ne m'a pas parlé de beau-papa ». Difference between the two groups was only noted during the course of sentence production. Indeed at other measurement points (P2 to P5), the curve of control subjects is well above that of patients in OFF DOPA, the difference between the two groups was significant ($p = 0.001$). It is also found that the curve of control subjects had a more stable pace with its roughly more linear shape (See Figure 3). This could reflect a greater mastery of oral airflow by control subjects. In other words, the relatively greater irregularity of the curve of average values of MOAF in patients could reinforce the idea of a less good control of the MOAF. The reported decrease of MOAF could merely be a consequence of the fall in IOP. For example, assuming that laryngeal resistance is constant, the drop in IOP necessarily induces a associated decrease of MOAF. However it seems exist in this study a large variability in laryngeal resistance in patients, as an overview was provided us in the morphological analysis of their value curves. This suggests a relatively fluctuating fall in MOAF which may also be related to tissue properties, configuration of the glottis and impedance of the vocal apparatus.[13] It is reported more generally in extrapyramidal syndromes glottic and supraglottic disorders such as movement disorders. These disorders can obstruct completely or partially the upper airway to induce sometimes severe airflow decrease.[14] The MOAF decline during speech production of PD patients could also be explained by similar mechanisms, among others.

Finally for the laryngeal resistance (LR), Parkinson's disease could induce a greater variability of this parameter in patients compared to control subjects, as evidenced by the general morphology of control subjects and OFF DOPA patients' curves. In other words, control subjects would have more stable values of LR, which would mean that Parkinson's disease induces instability of laryngeal resistance. The values of standard deviations significantly larger in OFF DOPA patients than control subjects, again reflecting greater variability in the values of LR at all measurement points, seem to confirm this trend (See Figure 5). The study of LR values distribution histogram in the two groups seems to be in the same direction. Indeed, the histogram shows a fairly symmetrical distribution for control subjects where OFF DOPA patients have more skewed distributions, with thus a tendency to give most often higher LR values compared to control subjects (See Figure 6).

Laryngeal resistance is equal to the ratio of IOP on MOAF; its greater constancy among control subjects may indicate a more perfect mastery of these two parameters. And besides this relative constancy of laryngeal resistance in control subjects was found in the measures which had been performed by Smitheran and Hixon to compare measurements of non-invasive technique for evaluation of laryngeal resistance that they had developed with those of invasive procedures previously used.[5] The mean laryngeal resistance in their patients was 35.7 + /– 3.3 cm H20/LPS (all measurements are between 30 and 43, 1). Blosser *et al.* reported similar values with a mean of 38.4 + /– 7.43 cm H20/LPS.[15] In addition laryngeal resistance may reflect the larynx subject behavior. This has been demonstrated in a canine animal model which is able of maintaining, like humans, a constant subglottic pressure during phonation. In this model it was found a significant rise in laryngeal resistance when increasing the recurrent laryngeal nerve stimulation while the same nerve paralysis induced a significant drop of laryngeal resistance.[16] This significant rise in LR was also found in other disease involving larynx impairment with patients 'average to 65 + / – 8.15 cm H20/LPS.[15] We can therefore assume that the instability of laryngeal resistance in OFF DOPA patients reflects a more variable behavior of their larynx, but also a greater fluctuation in IOP and MOAF. We know, as seen previously, that patients have IOP lower than those of control subjects at all measurement points. So the important rise of patients' laryngeal resistance in the first half of the sentence, beyond the intrinsic behavior of larynx, may result from a larger drop of their airflow as we had also seen. And then the decline in patients' IOP in the second half of the sentence would induce the consequent decline of their laryngeal resistance. That's why the global evolutionary pace of patients' curve shows increased laryngeal resistance in the first half of the sentence and significant drop in the second half. These high laryngeal resistances in the beginning of the sentence could be related to a lack of pneumophonic coordination, that is to say a kind of phase shift between the air expiratory thrust and resistance state of the larynx. Everything would go as if, when the expiratory air exerts its thrust, the larynx is still at resistance level higher than normal. The larynx would amount only to a resistance normal level later, which would explain the decrease of laryngeal resistance in the second half of the sentence. In short, this phenomenon simply imitate, but this time at the pneumophonic floor, the mechanism of control loss of voice onset time (VOT) which reflects a lack of coordination between the larynx and articulatory organs.[17,18]

It thus appears that there is in Parkinson's disease pneumophonic coordination impairments which are evidenced by the fall in IOP and that of MOAF in patients compared with control subjects. And it follows from the alteration of these two parameters a greater instability of laryngeal resistance which is none other than ratio of two above mentioned parameters. For didactic sake, we attempted to separately discuss the different parameters (IOP, MOAF and LR). However it should be borne in mind that these parameters are closely related functionally, and that any change in one inevitably has repercussions on the other two. Indeed, the SGP (reflected here by the IOP) depends on the air expiratory column thrust and laryngeal resistance (LR) while translaryngeal airflow (reflected here by the MOAF) is merely the result of the conflict between expiratory thrust forces (SGP) and laryngeal resistance (LR) forces.[11,12] Reported disturbances in the three parameters pose the problem of events' real chronology because of parameters' correlation. Is it the increase in RL at the beginning of the sentence which induces a fall in MOAF or, conversely, would it fall in MOAF resulting of expiratory thrust poor dynamic that would cause the increase in RL? It could probably be a simultaneous mechanism combining both alteration of expiratory dynamic (leading to fall in IOP and MOAF) and elevated laryngeal resistance notably at sentence beginning (reinforcing the fall in MOAF). Such a mechanism would both explain decrease in IOP and initial elevation of laryngeal resistance laryngeal which both lead to a decline in MOAF that patients would be tempted to correct the problem by vocal abuse. Finally, such a mechanism would fit perfectly to a lack of pneumophonic coordination imitating, as we noted above, the lack of coordination in phono-articulatory stage which induces the voice onset time (VOT).

Conclusion

Parkinson's disease, given the study of these three parameters, likely induces an alteration of pneumophonic co-ordination involving a decrease in IOP, a decrease in MOAF and instability of the LR. So the measurements of these three aerodynamics parameters, by reflecting the dysfunction induced by disease, may well be relevant factors in parkinsonian dysarthria evaluation. These parameters can also be valuable in evaluation of several therapies used in Parkinson's disease treatment in general and dysarthria in particular.

Conflicts of interest

No

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