

LARYNGOLOGY

Multidimensional voice assessment after Lee Silverman Voice Therapy (LSVT[®]) in Parkinson's disease

Valutazione multidimensionale della voce dopo riabilitazione vocale sec. Lee Silverman nei pazienti affetti da malattia di Parkinson

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SUMMARY

Objective. To investigate the effectiveness of Lee Silvermann Voice Treatment (LSVT[®]) in improving prosody in patients with Parkinson's disease over medium-term follow-up.

Methods. 15 patients with Parkinson's disease were assessed before LSVT[®], within one week, and 3 and 6 months after treatment. Subjective and objective evaluation included: Voice Handicap Index - 10 (VHI-10), perceptual assessment by GRBAS scale and item 18 of the Unified Parkinson's Disease Rating Scale III (UPDRS III), maximum phonation time (MPT /s/) and acoustic analysis by means the Voice Range Profile (VRP) and the "Intonation Stimulability Protocol" of the Motor Speech Profile (MSP).

Results. A significant increase of the mean values of I_{max} and rF₀ was observed until 6 months post-therapy (p < 0.001), whereas Running Speech Standard Deviation (rSTD) (p = 0.004), Amplitude Variability (rVAm) (p = 0.02) and Frequency Variability (rVF₀) (p = 0-01) improved significantly after 3 months, but returned to pre-therapy levels after 6 months. The score of item 18 of the UPDRS III increased significantly early post-therapy (p = 0.03), but did not maintain the improvement at 3 and 6 months. Median values of Grade (G), Asthenia (A) and mean values VHI-10 score significantly decreased at each post-therapy control (p < 0.05).

Conclusions. In addition to the subjective and perceptual beneficial effect of LSVT[®], we found a long-lasting increase of loudness and fundamental frequency. There was also improvement of acoustic parameters related to prosody, although it was temporary.

KEY WORDS: Parkinson's disease, Lee Silverman speech treatment, acoustic analysis, prosody, voice, dysarthria

RIASSUNTO

Obiettivo. Valutare l'efficacia del LSVT[®] nel migliorare gli aspetti prosodici dei pazienti con malattia di Parkinson.

Metodi. Sono stati valutati 15 pazienti subito dopo il LSVT[®] e nei follow-up a una settimana, a 3 e a 6 mesi dal termine del trattamento attraverso la somministrazione dei seguenti strumenti: Voice Handicap Index -10 (VHI-10), scala GRBAS, item 18 dell'Unified Parkinson's Disease Rating Scale III (UPDRS III), Tempo Massimo Fonatorio (TMF/s/), Voice Range Profile (VRP) e l'Intonation Stimulability Protocol del Motor Speech Profile (MSP).

Risultati. Dopo la terapia i parametri acustici I_{max} e rF₀ hanno mostrato un incremento significativo che si è mantenuto nel follow-up a 6 mesi (p < 0,001), mentre per le variabili rSTD (p = 0,004), rVAm (p = 0,02) e rVF₀ (p = 0-01) si è evidenziato un miglioramento significativo nel follow-up a 3 mesi che tuttavia non si è mantenuto nel successivo controllo a 6 mesi. Il punteggio dell'item 18 dell'UPDRS III ha mostrato un incremento significativo soltanto a una settimana dal termine del trattamento (p = 0,03). Infine si è evidenziato un miglioramento statisticamente significativo dei parametri G (Grado) e A (Astenia) della scala GRBAS così come del valore medio del VHI-10 sia subito dopo il LSVT[®] che nei successivi follow-up a 3 e a 6 mesi (p < 0,05).

Conclusioni. I risultati hanno evidenziato, oltre ad un miglioramento soggettivo e percettivo della sintomatologia, un incremento dell'intensità e della frequenza fondamentale. Il miglioramento dei parametri acustici relativi alla prosodia è stato temporaneo e non si è mantenuto nel tempo.

PAROLE CHIAVE: malattia di Parkinson, Lee Silverman voice treatment, analisi acustica, voce, prosodia, disartria

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Introduction

One of the most common voice symptoms and one of the primary targets of intervention in Parkinson's disease (PD) is reduced voice intensity. Parkinsonian hypokinetic dysarthria is mainly characterised by breathy and harsh voice, reduced loudness and monotonous speech. Loss in voice production, which occurs along with other speech problems, concerns the majority of patients with PD (90%)¹ and results in a decrease in familiar, social and professional interactions, as well as in isolation and consequent deterioration of quality of life². Although the neural mechanisms underlying vocal symptoms are not clear, the combination of bradykinesia/hypokinesia with psychological and sensory components is pointed out as being responsible for voice impairment³.

As medication and surgical treatments have only modest effects on parkinsonian speech^{4,7}, behavioural treatments are preferred⁸. Intensive voice therapy, specifically Lee Silverman Voice Treatment (LSVT®), has been shown to be highly effective⁹. LSVT® trains dysarthric patients with PD to speak louder while self-monitoring the effort required to produce that voice.

This method capitalises on the known effects of increased vocal effort and loudness on the respiratory, phonatory and articulatory subsystems of speech. LSVT® stimulates glottal closure with the aim of increasing vocal intensity and, even if purely focused on voice, of improving articulation by recalibrating the sensorimotor perception of the volume of voice¹⁰. LSVT® increases respiratory drive and improves oral resonance/vocal loudness through increased jaw movements¹¹. The result is better communication through reduction of vocal symptoms of the disease and adjustment of voice quality to personal and social needs. LSVT® has proven to be effective in Level I Scientific Evidence, and for years has been the treatment of choice for patients with PD as shown by the predominance of studies using it¹². A recent review by Yuan et al. (2020) noted that most trials have considered increased vocal loudness as the main outcome measure of treatment¹³, not focusing on prosody as another equally important outcome measure. In fact, it is well known that monotonic speech is one of the most characteristic aspects of parkinsonian dysarthria interfering with the naturalness of speech in these patients.

The aim of our study was to investigate the effectiveness of LSVT® in improving prosody in patients with PD, by using it a specific program for the first time – the “Intonation Stimulability Protocol” – included in the “Motor Speech Profile” (MSP) software (MSP-model 5141, Kay Elemetrics, Lincoln Park, NJ).

Materials and methods

Patients and setting

From April 2019 to November 2019, at the Phoniatic Unit of the Fondazione Policlinico Universitario “A. Gemelli” IRCCS in Rome, we enrolled patients affected by PD. The inclusion criteria were: PD diagnosed by an expert neurologist according to the *UK Parkinson's disease Brain Bank* criteria¹⁴; age between 40 and 80 years, H-Y stage no > III, able and willing to provide written informed consent. The exclusion criteria were the following: parkinsonism other than idiopathic PD, previous or current psychiatric problems or cognitive decline, history of voice or laryngeal disease requiring therapy or of pulmonary disease, previous neck surgery, past or present swallowing or voice rehabilitation therapy, bilateral high-frequency stimulation of subthalamic nucleus (STN). The subjects were studied by a team that included a neurologist trained in movement disorders, a speech-language pathologist with over 10 years of experience working with patients affected by PD, two otolaryngologists and two speech-language therapists.

Design

Patients were evaluated before treatment (pre-therapy), within one week after therapy (early post-therapy), and at three and six months after therapy. For each patient the functional assessment was always carried out at the same time of day, one hour after intake of a standardised dosage of levodopa. The author (MRM) involved with data collection was blind to the patients' status and treatment condition.

Voice therapy

LSVT® was conducted by four of the authors (C.AC, Y.L, G.M., I.P.), certified by LSVT Global Inc., according to its main treatment protocol, published by Ramig et al.¹⁵⁻¹⁷.

The treatment consists of 16 individual therapy sessions (four 1-hour sessions per week for 4 consecutive weeks) and involves multiple repetitions (15 times and more), maximum effort of the individuals, and daily tasks. The complexity of the training increases during the 4 weeks, with greater cognitive/motor load of the exercises, longer duration and higher difficulty of the “speech” tasks assignments. The exercises can be done at home. The treatment program was performed individually in a quiet room. Clinical assignments used in LSVT® were first translated into Italian by a speech and language pathologist who was fluent in both English and Italian.

Objective and subjective assessment

Stroboscopedaryngoscopy was performed by an expert, in-

dependent and blinded ENT physician (LD), using a flexible laryngoscope (model Xion GmbH Video-Nasopharyngoscope EV-NE) to exclude morphological abnormalities and motility impairment of the larynx.

Maximum phonation time (MPT /s/). This was obtained by having the patient sustain the vowel /a/ for as long as possible on a single breath. The longest of three attempts was calculated as MPT.

Perceptual voice analysis. Blind perceptual evaluation was performed on recorded voice samples (reading task of 184 words, 362 syllables and 26 sentences) by unfamiliar listeners with expertise in voice disorders. It comprised The Grade – Roughness – Breathiness – Asthenia – Strain (GRBAS) scale¹⁸ and item 18 of the Unified Parkinson's Disease Rating Scale III (UPDRS III), which requires rating speech on a 5-point Likert scale (from 0: Normal - no speech problems - to 4: Severe: most speech is difficult to understand or unintelligible).

Patient self-assessment. Assessment of dysphonia-related quality of life was carried out by using the Italian version of the Voice Handicap Index-10 (VHI-10)¹⁹.

Acoustic voice analysis. For acoustic voice analysis we used the Computerized Speech Lab model 4300B from Kay Elemetrics (Lincoln Park, NJ), recording with a Shure model SM48 microphone (Evanston IL) positioned at a 45° angle and at a distance of 20 cm from patient's mouth. The microphone saturation input was fixed at 6/9 of Channel 1 and the environmental noise was < 30 dB sound pressure level (SPL). The Voice Range Profile program (VRP-model 4326) was used to analyse speaking voice as described by D'Alatri and Marchese²⁰. Patients were asked to read twice 20 sentences aloud at their most comfortable pitch and loudness as in daily conversation. Subjects were allowed to practice reading the sentences aloud before actual recording. The sentences were chosen to be characterised by different prosodic features (*i.e.*: interrogative, affirmative, exclamatory) and to express different feelings (*i.e.*: happiness, sadness, disbelief, disappointment). After recording, the following parameters were analysed: lowest frequency (F_{\min} , Hz), the highest frequency (F_{\max} , Hz), number of semitones (st), minimum intensity (I_{\min} , dB SPL), maximum intensity (I_{\max} , dB SPL) and difference between I_{\max} and I_{\min} (range dB, dB SPL)

Motor Speech Profile (MSP– model 5141) analysis was performed by using the protocol “*Intonation stimulability*” that assesses the patient's ability to listen to a target speech token and then verbally match the target intonation pattern. Patients were asked to listen and to repeat the sentence “*Esci oggi o domani?*” ([‘ɛʃi ‘ɔdʒ:i /ʌ/ o_v do‘mani /ʌ/]) in which all the phonemes except one – the fricative palato-alveolar [ʃ] – are voiced. The sentence was mod-

eled with an upward and downward intonation to evaluate the ability to vary pitch and intensity during speech. In the recording, a sampling rate of 11025 Hz was used. The variables analysed with the “*Intonation Stimulability Protocol*” were: Running Speech Average Fundamental Frequency (rF_0 – Hz), Running Speech Highest Fundamental Frequency (rF_{hi} – Hz), Running Speech Lowest Fundamental Frequency (rF_{low} – Hz), Running Speech Standard Deviation of F_0 ($rSTD$ – Hz), Frequency Variability (rvF_0 – %) and Amplitude Variability ($rvAm$ – %). The parameters $rSTD$ and rvF_0 track the degree of pitch variations, low values suggesting a monotonic vocalisation. The parameter $rvAm$ tracks the degree of amplitude variability, a mono-level vocalisation corresponding to lower values of $rvAm$.

Statistical analysis

For statistical analysis we used the MedCalc package (version 12, Marienkerke, Belgium). Kolmogorov–Smirnov test was employed to assess the distribution of the continuous variables examined in the study. Parametric (repeated-measures ANOVA with Bonferroni correction and Student's t-test for paired data) and non-parametric tests (Wilcoxon) were applied depending on data distribution. The level of significance was set at $p < 0.05$.

Results

From a series of 23 patients, 8 (34.78%) did not meet inclusion criteria and 15 (65.2%) were thus considered. Of these, 14/15 (93.3%) cases were male and 1/15 (6.6%) was female, with a mean age of 71 ± 7 years (min. 58, max. 78 years). The mean time since diagnosis was 2.6 years (min. 1 and max 5 years).

Stroboscovideolaryngoscopy

None of the 15 cases had morphological abnormalities and motility impairment of the larynx.

Maximum phonation time (MPT)

Repeated-measures ANOVA showed no significant difference among the times of observation ($p > 0.05$). However, Student's t-test for paired data revealed that MPT significantly improved soon after the end of treatment (mean pre-therapy = 14.81 ± 9.10 s; mean early post-therapy = 17.81 ± 7.83 s, $p < 0.02$), whereas this MPT increase was no longer significant at 3 months (mean = 16.18 ± 6.82 s, $p > 0.05$) and 6 months post-therapy (mean = 15.27 ± 5.71 s, $p > 0.05$).

Acoustic voice analysis

VRP analysis by repeated-measures ANOVA showed a sig-

nificant increase of I_{\max} ($F(3, 34) = 11.03$; $p < 0.001$), and two-by-two comparisons demonstrated that the significant improvement was obtained immediately after treatment and maintained throughout follow-up. Repeated-measures ANOVA did not reveal a significant increase of F_{\max} over time ($p > 0.05$). By Student's t-test for paired data, significant improvement was found between pre-therapy and early post-therapy ($p = 0.01$), and F_{\max} tended to decrease at 3 and 6 months post-therapy. At repeated-measures ANOVA, the increase in intensity range (dB) was nearly significant ($p = 0.07$). As for the above-mentioned variables, Student's t-test for paired data showed significant improvement between pre-therapy and early post-therapy, after which a decreasing trend was observed. The comparison between pre-therapy, early post-therapy, 3 and 6 months post-therapy did not detect significant differences in the mean number of semitones or mean values of I_{\min} and F_{\min} ($p > 0.05$). All data on acoustic voice analysis are detailed in Table I. At repeated-measures ANOVA, no significant improvement of the rF_0 variable was observed over time. Nevertheless, Student's t-test for paired data showed significant improvement between pre-therapy and early post-therapy ($p < 0.001$). These results remained stable at 3 and 6 months after therapy. Similarly, the rvF_0 and $rSTD$ variables did not increase over time. However, for the rvF_0 variable Student's t-test for paired data showed significant improvement between pre-therapy and 3 months post-therapy

($p = 0.01$) and for $rSTD$ values Student's t-test for paired data resulted in a significant increase between pre-therapy and 3 months post-therapy ($p = 0.004$). With regards to the $rvAm$ variable, repeated-measures ANOVA showed significant improvement over time ($F(3, 35) = 39.60$; $p = 0.02$), with significant differences between both pre-therapy and early post-therapy, and between early post-therapy and 3 months post-therapy.

Regarding rF_{hi} and rF_{low} variables, no significant increase was found over time at repeated-measures ANOVA nor at two-by-two comparisons by Student's t-test. Details concerning the variables rF_0 , rvF_0 , $rSTD$, $rvAm$, rF_{hi} and rF_{Lo} are reported in Table II.

Perceptual voice analysis

A Wilcoxon Test was applied in order to analyse GRBAS and item 18 of UPDRS III scores. The Grade (G) variable decreased significantly between pre-therapy and early post-therapy ($p = 0.003$) and between pre-therapy and the two follow-up assessments after 3 ($p = 0.007$) and 6 months ($p = 0.03$). At the early and 3 months post-therapy time points, median values for Asthenia (A) were significantly decreased compared with pre-therapy ones ($p = 0.03$; $p = 0.01$ respectively) (Fig. 1).

With regards to the UPDRS III results, the score of item 18 significantly improved at the early post-therapy control (median pre-therapy = 1, median early post-therapy = 0,

Table I. The results of speech range profile before and after LSVT®.

	Pre LSVT®	Early Post-LSVT®	3 months post-LSVT®	6 months post-LSVT®
I_{\min} (dB SPL)	70.91 ± 2.70	72.09 ± 3.08	71.83 ± 2.71	72.13 ± 3.68
I_{\max} (dB SPL)	89.82 ± 4.07	97.45 ± 2.66 *	96 ± 3.85 *	95.13 ± 3 *
F_{\min} (/Hz)	122.24 ± 27.29	125.63 ± 30.82	125.40 ± 24.23	130.45 ± 27.32
F_{\max} (/Hz)	224 ± 39	268 ± 70 *	253 ± 61.39	246.31 ± 37.27
N. of semitones	10.73 ± 2.24	12 ± 4.98	12.50 ± 3.67	11.88 ± 1.81
range dB	18.90 ± 2.91	25.36 ± 2.54*	17.63 ± 11.70	16.72 ± 10.90

* vs pre-therapy ($p < 0.05$). I_{\min} : minimal Intensity; I_{\max} : maximum Intensity; F_{\min} : minimal Frequency; F_{\max} : maximum Frequency.

Table II. Values obtained before and after therapy by the Intonation Stimulability Protocol.

	Pre LSVT®	Early Post-LSVT®	3 months post-LSVT®	6 months post-LSVT®
rF_0 (/Hz)	173.18 ± 27.64	199.63 ± 39.59*	201.36 ± 34.57 *	200.63 ± 34.14 *
rF_{hi} (/Hz)	265 ± 52.54	282.73 ± 58.25	283.72 ± 59.38	279.18 ± 55.80
rF_{low} (/Hz)	112.29 ± 19.65	122.98 ± 44.72	133.22 ± 45 *	124.21 ± 34.23
$rSTD$ (/Hz)	23.77 ± 8.81	30.38 ± 14.63	36.24 ± 17.31 *	24.07 ± 16.79
rvF_0 (/%)	13.11 ± 4.08	15.35 ± 5.84	18.54 ± 8.46*	14.46 ± 5.07
$rvAm$ (/%)	36.34 ± 4.14	43.20 ± 7.35*	44.69 ± 8.15 *	40.21 ± 3.57

* = $p < 0.05$ vs pre-LSVT®. rF_0 : Running Speech Average Fundamental Frequency; rF_{hi} : Running Speech Highest Fundamental Frequency; rF_{low} : Running Speech Lowest Fundamental Frequency; $rSTD$: Running Speech Standard Deviation of F_0 ; rvF_0 : Frequency Variability; $rvAm$: Amplitude Variability.

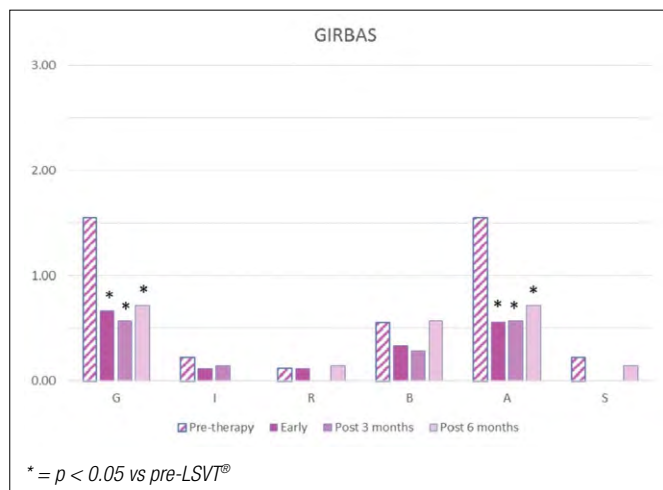


Figure 1. Results of perceptive assessment basing on the GIRBAS scale.

$p = 0.03$), but it did not at the 3 and 6 months post-therapy follow-up ($p > 0.05$).

Patient self-assessment

The VHI-10 mean scores before and after voice therapy are shown in Figure 2. The mean values analysed by repeated-measures ANOVA did not detect any significant decrement over time. Nevertheless, Student’s t-test for paired data revealed a significant improvement ($p = 0.04$) between pre-therapy (mean = 16.67 ± 8.63) and early post-therapy (mean = 11.23 ± 5.80), and between pre-therapy and the two follow-up assessments at 3 (mean 10.57 ± 10.70) ($p = 0.01$) and 6 months (mean = 10.14 ± 6.64) ($p = 0.01$), as shown in Figure 2.

Discussion and conclusions

The aim of this study was to investigate the effectiveness of LSVT® in improving prosody in patients with PD. For this purpose, we analysed the acoustic parameters related to prosody using software specifically designed for motor speech disorders.

Clinical research²¹⁻²³ on PD has demonstrated that, even if dysarthria may impact all speech subsystems, vocal loudness and prosody are the most affected, impairing naturalness and speech intelligibility.

Ramig et al.^{15,16} demonstrated that LSVT® improves both parameters related to vocal loudness (e.g. SPL during vowels and reading) and those related to prosody (e.g. fundamental frequency variability in monologue, inflection in voice fundamental frequency), even in the long term.

In our group of patients, the mean values of I_{max} as well as those of rF_0 increased significantly immediately after

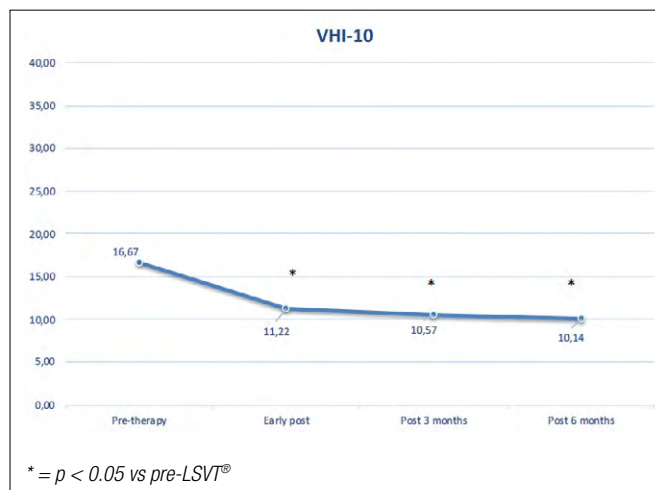


Figure 2. Self-assessment results (VHI-10) before and after therapy.

LSVT® and did not change until the last follow-up. The simultaneous increase in intensity and frequency was predictable, since, as is known, the fundamental frequency increases with intensity²¹.

In contrast with Ramig et al.^{15,16}, the increase in the average fundamental frequency of running speech we observed in our patients after therapy did not relate to improvement in prosody. Indeed, in our study the prosody-related acoustic parameters - rSTD, rvF0 and rvAm - showed a significant increase in the medium term, but did not preserve the effect at the last control.

Subjectively, patients showed a significant decrease in voice-related quality of life immediately after therapy and at each time of follow-up. The overall perception of the severity of dysphonia improved until the 6-month control, in particular due to the decrease in Grade and Asthenia, as also confirmed by the results of VHI-10.

Works assessing vocal function after LSVT® described long-term improvement (up to 2 years) basing both on acoustic (SPL and semitone standard deviation)¹⁵ and perceptual data¹⁵⁻¹⁷. Our results show that, thanks to the increase in vocal fold tension and subglottal pressure associated with the increase in volume, LSVT® allows patients to improve vocal fold adduction and the activation and synergy of the laryngeal muscle, thus making the phonatory system more efficient over time.

On the contrary, the recovery of prosody proved to be slower and temporary. It cannot be excluded that rehabilitation of muscle activity aimed at intonation is more difficult and may require repeated therapy cycles to obtain more stable acoustic results. In this regard, the central sensory processing and cueing deficits found in subjects with PD may also play a role. In particular, in patients with PD a selective

difficulty in recognising emotions from prosody and a general defect in prosody processing has been demonstrated²³. One further element that is worth discussing is the fact that several variables considered in our study (MPT, F_{\max} , range dB, rF_{low} , rSTD, rvF_0 , $rvAm$) improved significantly immediately after therapy or in the medium-term follow-up, but tended to decrease during long-term follow-up, and in some cases even regressing to pre-therapy levels. This finding has never been reported in the literature and may be explained by considering that LSVT® must necessarily be continued by patients themselves once treatment in presence is concluded. This could result difficult to obtain in patients that are seldom monitored in their self-training and need continuous family involvement. Finally, long-term improvements can be compromised by a worsening of general clinical conditions, as is often the case with PD.

Further studies are needed to confirm these results by analysing speech outcomes using tools more specific for PD patients as the Italian protocol for dysarthria (QoL-Dys)²⁴ and the Italian version of the Frenchay dysarthria Assessment (FDA)²⁵.

Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

MRM: design of the study, interpretation of the data and manuscript writing, revision and final approval. IP: acquisition, analysis and interpretation of data, revision and final approval of manuscript. YL: acquisition, analysis and interpretation of the data and manuscript revision. GM: statistical analysis and interpretation of the data, manuscript writing, revision and final approval. CAC: acquisition, analysis and interpretation of data, revision and final approval of manuscript. LD'A: design of the study, interpretation of data, revision and final approval of the manuscript.

Ethical consideration

This research work was conducted in accordance with the principles contained in the Helsinki declaration and was approved by the institutional review board (Fondazione Policlinico Gemelli, Protocol number: 0038806/21). A written consent was obtained from all the patients included in the study after being informed verbally about the aim of the study.

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