Effects of Exercise Through Telerehabilitation on Balance and Walking Speed in Older Adults with Diabetic Peripheral Neuropathy: A Randomized Controlled Trial

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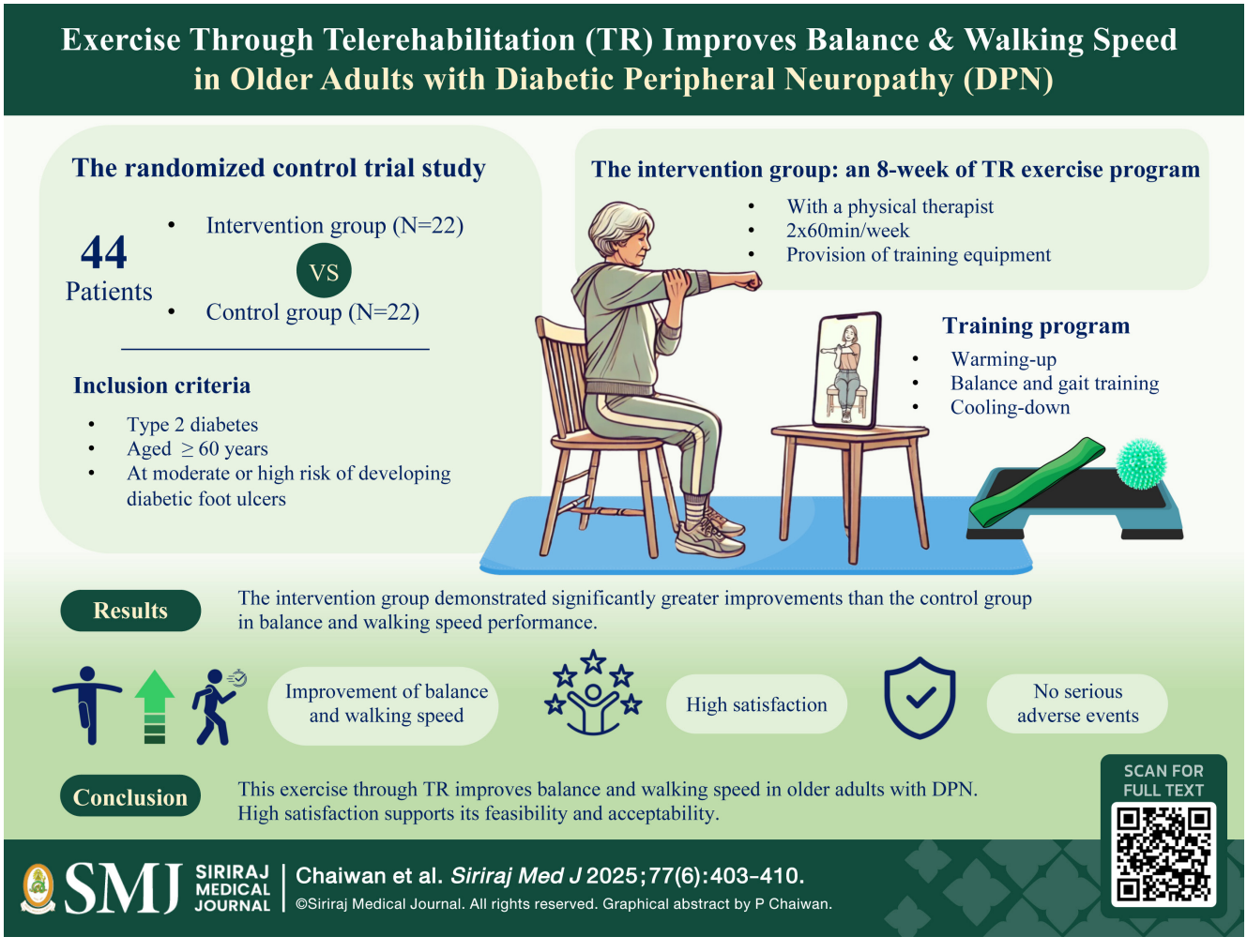

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ABSTRACT

Objective: Determine the effects of exercise through telerehabilitation (TR) on balance and walking speed in older adults with diabetic peripheral neuropathy (DPN).

Materials and Methods: An observer blinded randomized controlled trial was conducted at Sirindhorn School of Prosthetics and Orthotics. Participants age ≥60 years with type 2 diabetes, DPN, and a moderate to high risk of diabetic foot ulcer were randomly assigned to an intervention group who underwent an eight-week TR exercise program (2 x 60 min/week) and a control group who received standard hospital care. Outcome measures were balance (Berg Balance Scale, BBS), walking speed (10-Meter Walk Test, 10MWT), and satisfaction. Differences in change between the groups were analyzed using Mann Whitney U (MWU) test or t-test for independent samples.

Results: Forty-four participants were included (intervention: n=22; control: n=22), with 18 and 21 completing the study, respectively. The median age [IQR] was 69.5 [63, 72.8] years in the intervention group and 67 [65, 74] years in the control group. No differences between groups were found in baseline characteristics and initial outcomes. The intervention group demonstrated significantly greater improvements than the control group in BBS scores (median change [IQR]: 6.5 [4.8, 5.2] vs. -1 [-1, -2], P<0.001, MWU test) and 10MWT time (mean change -1.9 seconds [95% CI: -2.5, -1.3] vs. -0.1 seconds [95% CI: -0.5, 0.4], P<0.001, independent t-test). The intervention group was highly satisfied with the program.

Conclusion: This exercise through TR improves balance and walking speed in older adults with DPN. High satisfaction supports its feasibility and acceptability.

Keywords: Balance; diabetes; exercise; telerehabilitation; walking speed (Siriraj Med J 2025; 77: 403-410)

INTRODUCTION

According to the International Diabetes Federation 2021, diabetes is a rapidly escalating global health crisis in the 21st century. The report estimated that around 537 million adults (20-79 years) were living with diabetes in 2021, which is estimated to increase to 643 million by 2030, and 783 million by 2045.[1] Type 2 diabetes (T2DM) is the most prevalent type of diabetes, representing about 90% of all diabetes cases worldwide.[2] One of the most prevalent chronic complications of diabetes is diabetic peripheral neuropathy (DPN), characterized by paresthesia, especially in the feet and hands.[3] DPN can lead to decreased proprioception[4], reduced foot-ankle range of motion, and diminished muscle strength[5,6], resulting in impaired postural stability, functional gait, and balance. These impairments significantly increase the risk of falls, especially in older adults. Moreover, DPN is a major cause of foot ulceration and amputation.[7-10]

Exercise has been an essential aspect of non-pharmacological treatment for DPN.[11] Evidence suggests that exercise programs, including walking, balance training, and lower limb strengthening exercises, can decrease the risk of falls in older adults with DPN.[12-16] However, many patients are unable to participate in the offered exercise programs due to barriers such as long-distance travel or work commitments.[17] During the COVID-19 pandemic, physical therapists (PTs) adapted their practices to maintain rehabilitation services while adhering to healthcare safety measures. Some PTs began implementing telerehabilitation (TR).[18] TR, a system to manage or monitor remote rehabilitation through communication technologies might be an option.[19] This approach not only saves time and resources in healthcare, but also provides convenience and flexibility, allowing information to reach a broader audience, including those in remote areas.[19,20]

Therefore, we developed an exercise program for balance and gait training, amid the COVID-19 pandemic. This program was delivered through TR and supervised by a PT. Thus, this study aimed to analyze effects of TR-based exercise program on balance and walking speed in older adults with DPN compared to no intervention.

MATERIALS AND METHODS

Research design

This observer-blinded randomized controlled trial was conducted at the Sirindhorn School of Prosthetics and Orthotics (SSPO), Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand, between October 2021 and January 2024. The study conformed to the guidelines of the Declaration of Helsinki was approved by the Siriraj Institutional Review Board with a certificate of approval (COA) no. Si 821/2021. After informed consent participants were randomly assigned to an intervention group or a control group. Randomization was conducted by an independent researcher using a computer-generated

randomization list to ensure allocation concealment. Participants were assigned to their respective groups based on the sequential order of the randomization list.

Participants

Patients with T2DM were recruited from the diabetic foot clinic at SSPO and the Siriraj Diabetes Center of Excellence, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok by clinical staff. Included were people, 1) diagnosed with T2DM and DPN at moderate or high risk of developing diabetic foot ulcers (DFU) as diagnosed by physicians[21]; 2) 60 years or older; 3) capable of walking and exercising independently without the need for assistive devices; 4) having a caregiver or someone present while exercising at home; 5) capable of using a smartphone or laptop for the TR program. Excluded were people with 1) an active foot ulcer; 2) baseline Berg Balance Scale (BBS) score below 45; 3) history of amputations; 4) orthopedic or surgical issues in the lower extremities such as fractures, malformations, or severe osteoarthritis; 5) presence of other neurological impairments, central nervous system problems, or vestibular system disorders; 6) severe retinopathy and/or nephropathy; 7) severe cardiopulmonary conditions or abnormal electrocardiogram results; 8) postural hypotension or uncontrolled hypertension; 9) poor vision; 10) intellectual disabilities or psychiatric disorders.

Intervention

All exercises included in the training program are described in Supplementary Material (https://doi.org/10.6084/m9.figshare.27991079.v3). The training program, partly based on previous studies[15,16], was developed by our team to enhance balance and gait training in a TR setting. Two PTs participated in this study. An observer, blinded to group allocation assessed pre- and post-intervention outcomes. A PT administered the exercises through TR. Participants in the intervention group received logbook that included the home-based exercise program as well as educational materials for self-care. Individuals accessed TR services through an online platform (LINE application) with the PT. Training time was 60 minutes, twice a week for 8 weeks on non-consecutive days. During training, the participants wore sport shoes or therapeutic shoes, which are custom-made to protect sensitive feet, reduce pressure, and provide support for patients' conditions, prescribed by a physician and worn with socks. The standardized training equipment consisted of 1) a training mat, 2) a sensory massage ball, diameter of 7.5 cm, 3) a lightweight elastic band, and 4) a step board size 28x78x20 cm. The training program was structured into three components: warming-up, balance and gait training, and cooling-down (Table 1).

Participants in the control group did not receive an exercise program, but received usual hospital medical care. In addition, both groups received pamphlets written by interdisciplinary teams at Siriraj Diabetes Center of Excellence covering topics such as diabetic foot care, diabetic diet, and diabetes complications.

Outcome measures

All participants were assessed using the Berg Balance Scale (BBS) and the 10 Meter Walk Test (10MWT) by the observer at baseline (T0) and after an 8-week follow-up (T1). Furthermore, during the final evaluation, the intervention group filled in a satisfaction questionnaire.

The BBS assesses static and dynamic balance capabilities and it consists of 14 items, each item is graded on a five-point scale (0 to 4) based on the quality of the performance of the item. The maximum score is 56. A score below 45 indicates a higher risk of falling.[8,22] The tool demonstrates responsiveness to changes in balance.

The 10MWT measures the time needed to walk a distance of 10 meters on a 14-meter walkway. The participants walked at a comfortable speed. The mean time (in seconds) of three trials was analyzed, with a 2-minute rest between each trial.[23]

Assessment of satisfaction concerning the exercise program, included six items (1) How would you rate the appropriateness of the duration of each training session, around 1 hour?, (2) How would you rate the quality of the training and equipment?, (3) Did the physical therapist explain the exercises in a way that was easy to understand?, (4) Do you feel that the physical therapist treated you with respect and dignity?, (5) Would you recommend this exercise program to a friend or family member?, (6) How would you rate the overall quality of the program delivered via an online platform? These items could be rated as; 1 = unsatisfied, 2 = poor, 3 = fair, 4 = good, or 5 = excellent.

Sample size calculation

The sample size calculation for this study was calculated using G*Power software, based on a randomized controlled trial with a 1:1 ratio of intervention group and control group.[16] That study reported a mean change of 2.1 for the intervention group and 0.1 for the control group in BBS outcomes, with standard deviations (SD) of 2.3 for both groups Assuming a power of 80% and an alpha of 0.05, the resulting effect size was 0.87. The required sample size was 44 participants, with 22 participants per group.

TABLE 1. Outline of the Siriraj Exercise Protocol.

Exercise	Composition
Warming-up (10 minutes)	Stretching: Neck muscles, posterior shoulder, triceps brachii stretch with side bend, hamstrings, gluteus and lower back, quadriceps, calf (10 seconds/3reps/side)
Balance and gait training (40 minutes)	Part 1: Balance training on a training mat - Bipedal heel and toe raise (10 reps/3 sets) - One-leg stance (10 seconds/3 reps/side) Rest: Sitting on a chair with a resistance band exercise (10 reps/3 sets) - Chest press - Middle back band pull-apart Part 2: Progressive balance and gait training on a training mat - Tandem stance (10 seconds/10 reps/side) - Backward walking (10 reps) - Sideways walking (10 reps/side) Part 3: Exercises on a step board (10 reps/direction/side) - Step-ups: front step-ups and side step-ups - Weight shifting: forward and side-to-side
Cooling-down (10 minutes)	- Sensory ball massaging (10 reps/side) - Foot writing the number 1 to 10 in the air (10 reps/side) - Towel curl (10 reps/3 sets) - Deep breathing (5 reps)

Abbreviation: Reps = repetitions

Statistical analysis

Statistical analyzes were performed using IBM SPSS Statistics, Version 29.0.2.0. The Shapiro-Wilk test was employed to assess the normality of the distribution for all parameters. Baseline differences between groups were evaluated using Student's *t* test or the Mann-Whitney *U* test for continuous variables and the Chi-square test for categorical variables. Differences in changes between groups were analyzed using an independent samples t-test or Mann-Whitney U test depending on data distribution. A significance level of $P < 0.05$ was considered statistically significant for all tests.

RESULTS

Forty-eight individuals were assessed for eligibility, and a total of forty-four participants were randomized into either the intervention group (n=22) or the control group (n=22). Finally, 18 participants in the intervention group and 21 participants in the control group were analyzed (Fig 1). There were no significant differences in the baseline characteristics between the two groups ($P>0.05$) (Table 2). No serious adverse events of the programs were reported.

Berg balance scale

The improvement in the BBS were significantly larger in the intervention group, (median change [IQR]: 6.5 [4.8, 5.2] than the control group (median change [IQR]: -1 [-1, -2]), P<0.001, MWU test (Table 3).

10 Meter walk test

The improvements in 10MWT were significantly larger in the intervention group (mean change -1.9 seconds [95% CI: -2.5, -1.3]) than the control group (mean change -0.1 seconds [95% CI: -0.5, 0.4]), P<0.001, independent t-test) (Table 3).

The satisfaction with the exercise program

Among the 18 participants who completed the survey, 17 rated the duration of each training session as

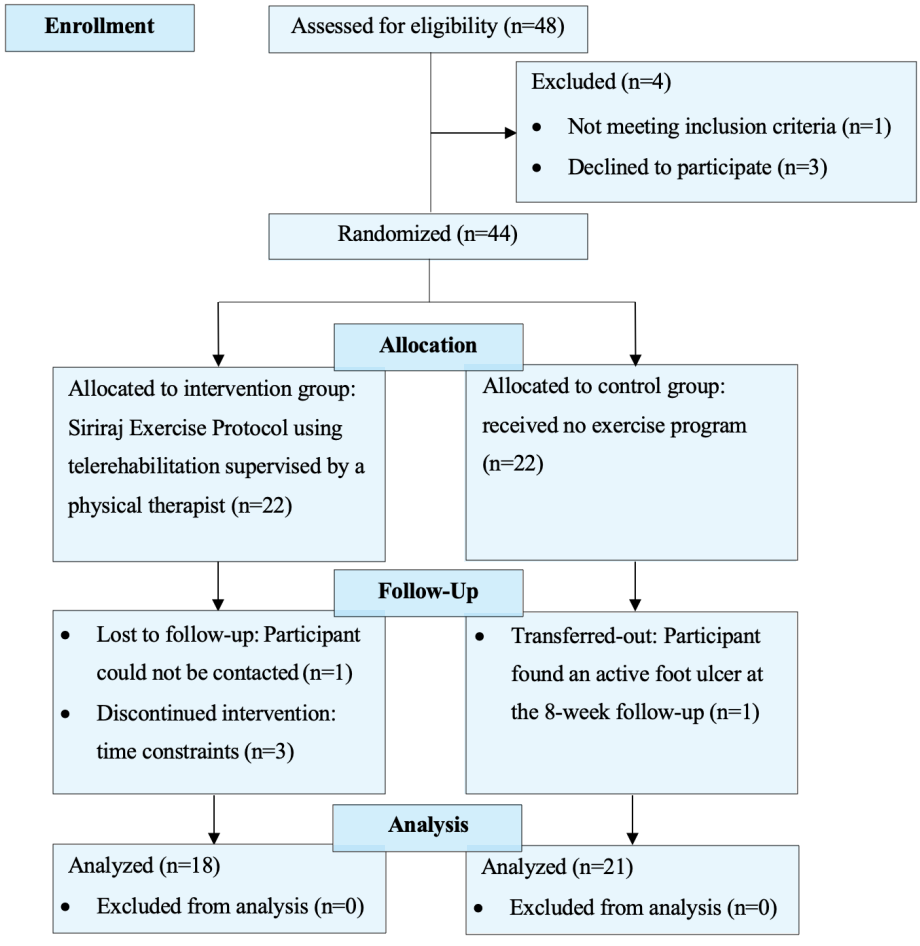

Fig 1. Flow diagram of the study.

excellent. 16 rated the quality of training and equipment as excellent, and 17 reported that the PT explained the exercises in a way that was easy to understand with excellent. All participants felt they were treated with respect and dignity by the PT. Additionally, 16 of participants would recommend this exercise program to a friend or family member, and 17 rated the overall quality of the program through the online platform as excellent.

DISCUSSION

This exercise program delivered by a PT via TR resulted in significant improvements in balance and walking speed in older adults with DPN. In the control group BBS score deteriorated highlighting the negative impact of physical inactivity or insufficient exercise. This result is consistent with previous findings that older adults with T2DM rapidly decline in leg muscle strength and muscle quality.[24]

Throughout the 8-week of training, no serious adverse events or diabetic foot ulcers were observed among participants in the intervention group. This finding challenges the historical advice for people with DPN to reduce weight-bearing activity.[25] However, lack of physical activity can result in deterioration of skin health and decrease in total body tolerance.[26,27] A previous study confirmed that weight-bearing exercises significantly improved daily step count and 6-minute walk test compared to non-weight-bearing exercises.[28] Moreover, increased weight-bearing activity did not lead to an increased risk of re-ulceration in diabetic foot.[29]

In this study, we selected an 8-week, twice-weekly training program based on the findings of a previous study, which reported significant improvements in balance and trunk proprioception were found following an on-site training.[16] We delivered our program through TR, highlighting the potential of remote training to achieve similar benefits.

To improve balance performance, balance exercises should be performed 2-3 days a week to enhance postural ability and gait, thereby reducing the risk of falling. Stretching exercises should be performed to the point of tightness for 10-30 seconds with 2-4 repetitions to improve joint range of motion.[30] The American Diabetes Association[31] guidelines emphasize the importance of regular exercise for older adults managing T2DM to promote overall physical function and prevent mobility-related complications.

TABLE 2. Baseline characteristics of both groups.

Characteristic	Intervention Group (n=18)	Control Group (n=21)	*P*
Age (y), median [IQR]	69.5 [63, 72.8]	67 [65, 74]	0.944†
Sex			1.000
Men, n (%)	6 (33%)	7 (33%)	
Women, n (%)	12 (67%)	14 (67%)	
Height (cm), mean ± SD	160.5 ± 8.4	157.9 ± 6.7	0.282*
Weight (kg), median [IQR]	64.9 [60, 81.5]	62 [57, 68]	0.118†
Body mass index (kg/m^2), mean ± SD	27.3 ± 5.2	25 ± 4.0	0.132*
Fasting blood glucose (mg/dL), median [IQR]	134.5 [122.5, 153]	129 [115, 150]	0.278†
Diabetes duration (y), median [IQR]	15 [10, 26.5]	23 [14, 30]	0.525†
Number of falls (n), median [IQR]	2 [1, 3.8]	1 [1, 3]	0.201†
The risk of foot ulceration			0.173
Moderate risk, n (%)	8 (44%)	5 (24%)	
High risk, n (%)	10 (56%)	16 (76%)	
Medication			0.233
Oral hypoglycemic agent, n (%)	13 (72%)	12 (57%)	
Insulin injection, n (%)	0	3 (14%)	
Both, n (%)	5 (28%)	6 (29%)	
Smoking			1.000
Yes, n (%)	1 (6%)	1 (5%)	
No, n (%)	17 (94%)	20 (95%)	

* Result of Student *t* test.
† Result of Mann-Whitney U test; otherwise by Chi-square test.

TABLE 3. Results of the Berg Balance Scale (BBS) and the 10 Meter Walk Test (10MWT) evaluated baseline and 8-week follow-up within the group.

Outcomes	Intervention group		Control group		Intervention group	Control group	*P* Value of difference in change between groups
	T0	T1	T0	T1	Change	Change	
BBS (score) (median [IQR])	48.5 [47, 50.8] NS	55 [51.8, 56]	47 [46, 50] NS	46 [45, 48]	6.5 [4.8, 5.2]	-1 [-1, -2]	<0.001†
10MWT (second) (mean ± SD)	11.8 ± 3.6 NS	9.9 ± 3.3	12.8 ± 3.4 NS	12.8 ± 3.5	-1.9 [95%CI: -2.5, -1.3]	-0.1 [95%CI: -0.5, 0.4)	<0.001*

T0 = at baseline, T1 = at 8 weeks of follow-up, BBS = Berg Balance Scale, 10MWT = 10 Meter Walk Test.
NS = Not significant difference at baseline between groups (P > 0.05).
† Result of the Mann-Whitney *U* test.
* Result of Student's paired *t* test.

Improved walking speed is critical to maintaining functional mobility and independence in older adults. Brisk walking (4-8 km/hour) significantly increases the chance of maintaining in functional mobility and independence in T2DM compared to slower paces.[32] In this study, the intervention group showed an improvement in walking speed (10MWT) from 3.1 km/hour to 3.6 km/hour but that is still speed that is less than the desirable speed of 4 km/hour.

Our study utilized TR intervention delivered through real-time video conferencing, allowing participants to receive direct supervision and feedback from the PT. This approach enabled participants to maintain social distancing during the pandemic while continuing supervised exercise at home. The program is simple and uses affordable equipment, easy to implement, and suitable for home-based settings. Furthermore, the high satisfaction reported in the survey supports the feasibility and acceptability of this exercise program among participants. Similarly, a recent study reported that a 6-week (3 times/week) supervised home-based TR program combining aerobic and resistance exercises significantly improved glycemic control, six-minute walk test performance, muscle strength, and quality of life in patients with T2DM. TR addresses barriers to exercise participation by being accessible, making it a viable alternative to traditional in-person programs.[33]

This study has several limitations. First, the sample size was below the estimated target. The inclusion criteria required older adults to be able to use a smartphone for TR, which posed challenges for some participants due to technological difficulties and the COVID-19 situation, caused temporary research pauses. Second, the study duration was limited to 8 weeks, which may not capture the long-term effects of the intervention. Future studies should include larger sample sizes and longer follow-up periods to assess the sustainability of the observed improvements. Third, the control group received only standard hospital care. Future studies should consider another intervention such as those participating in alternative home-based exercise programs (e.g., cycling on a home trainer), to assess whether similar improvements could be achieved with other intervention designs.

CONCLUSION

This exercise program through TR increases balance and walking speed in older adults with DPN. The high levels of participant satisfaction further support its feasibility and acceptability. These findings suggest that TR could be a valuable tool in the management of DPN, offering a flexible and accessible approach to rehabilitation.

Data Availability Statement

The data of this study and details regarding the exercise program are available on Figshare at https://doi.org/10.6084/m9.figshare.27991079.v3.

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DECLARATION

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Conflict of Interest

No potential conflict of interest was reported by the authors.

Registration Number of Clinical Trial

This study protocol was not registered in a trial registry.

Author Contributions

Conceptualization and methodology, P.C., G.S., P.P., and P.A. ; Provision of patients, N.J. ; Data collection and data acquisition, P.C. and P.A. ; Formal analysis, P.C. and G.S. ; Visualization and writing – original draft, P.C. ; Writing – review and editing, G.S. ; Supervision, G.S. and P.P. All authors - Final approval of the version to be published.

Use of Artificial Intelligence

No artificial intelligence tools were used in the writing of this research.

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