ORIGINAL ARTICLE

Assessing the Impact of Infographics Messaging via Mobile Chat Application on HbA1c Levels and Behavior in Diabetic Patients: A Randomized Controlled Study

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Background: Lifestyle modification is the most important method for preventing diabetes and disease progression. Mobile-health technology studies show positive results in diabetic patients in developed countries, however, the results in developing countries are controversial.

Objective: To assess the impact of infographic messaging on HbA1c levels and behavior in diabetic patients.

Materials and Methods: A randomized controlled trial was conducted involving 165 diabetic patients from Chaiyaphum Hospital. Participants were randomized into a control group and a messaged group, with messages sent approximately three times per week to the latter. Follow-up assessments were conducted every three months for a total of nine months, measuring HbA1c, fasting blood glucose, blood pressure, and behavior using a questionnaire. The primary outcome measure was the rate of HbA1c change per visit. Regression analysis of repeated measures was performed to compare the mean difference between the groups.

Results: Baseline characteristics were similar between groups, with no significant differences found. Overall, there was no significant difference in adjusted HbA1c change rate between groups (0.04, 95% CI –0.14 to 0.22, p=0.653). Subgroup analysis revealed no significant difference in patients receiving insulin treatment (–0.002, 95% CI –0.39 to 0.38, p=0.991). However, a significant decrease in the adjusted HbA1c change rate was observed in the messaged group for patients not receiving insulin treatment (–0.67, 95% CI –0.93 to –0.4, p<0.001). The messaged group also demonstrated a significant decrease in bad-behavior score (4.75±2.4, 95% CI 0.02 to 9.51, p=0.025).

Conclusion: While infographic messaging via mobile phone chat application did not significantly reduce HbA1c levels in diabetic patients overall, it effectively improved diabetic behavior. Notably, for patients without insulin treatment, the intervention led to a significant decrease in adjusted HbA1c change rate, suggesting its potential effectiveness in this subgroup.

Keywords: Diabetes; Electronic message; Mobile application; Infographics messaging

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Diabetes mellitus is a significant global public health problem that can result in several cardiovascular diseases, including coronary artery disease, cerebrovascular disease, and chronic kidney disease. It is also a significant public health problem in Thailand, where it was responsible for around 18 deaths per hundred thousand people in 2015. Moreover, the mortality rate associated with diabetes has been gradually increasing over the past few decades[1], probably caused by the gradual increase in the prevalence of this disease in Thailand[2-4].

Lifestyle modification is a vital part of the strategy for preventing and slowing the progression of diabetes[5-8]. However, this approach usually requires inputs from multidisciplinary teams, which are often time- and resource-consuming and, thus, not feasible in developing countries like Thailand.

The advancement of technology has resulted in many routes of communication between people that are faster, more convenient, and accessible than traditional face-to-face interactions. This technology has been utilized in healthcare, and several studies have demonstrated that the use of mobile phone technology such as mobile applications[9] and text-based messaging[10-12] can help improve a patient's behavior and glycated hemoglobin (HbA1c) levels. However, most of these studies were conducted in

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developed countries[13-17].

The use of mobile phone technology might not be as effective in developing countries like Thailand because of factors that include language barriers, unfamiliarity with applications or platforms, and education level[18-22]. The current study investigated whether such technology is useful in a developing country. To minimize language and unfamiliarity, barrier infographics messages were used rather than text messages alone, through the widely used mobile chat application "Line", which has 42 million users out of 66 million Thai people.

Materials and Methods

Study design

The present study was a nine-month, two-arm, parallel-group randomized trial. The participants were recruited from the outpatient clinic of Chaiyaphum Hospital between February 2018 and June 2019. Participants were randomly divided into two groups in a 1:1 ratio, the messaged group and the conventionally treated control group. The present study received ethical approval from the Chaiyaphum Hospital Ethics Committee (CPH.REC No11/61).

Participants

Patients were eligible if they were aged 15 years or older and had poorly controlled type 1 or type 2 diabetes, which was defined as a HbA1c concentration of 7.5% or greater within the three months before recruitment. Participants were required to have a mobile phone. Pregnant women were excluded. All patients provided written informed consent before their enrollment.

Randomization and blinding

Eligible participants were randomized to either the messaged group or control group in a 1:1 ratio. The randomization sequence was generated by a computer program, randomization.com, using a block of four. Treatment allocation was concealed until the point of randomization. Due to the nature of the intervention, participants were aware of treatment allocation, and an investigator broadcasted the graphic base message, thus, was not blinded. However, the investigator had no role in direct patient care or data collection. The rest of the team was unaware of the treatment allocation.

Procedures

After randomization and depending on the group assignment, participants were asked to scan the QR code to become a friend on the Line application. They then needed to complete a questionnaire at baseline and the nine-month follow-up via a link on their Line application. Information collected from the questionnaire included baseline characteristics such as age, gender, body weight, height, education level, and occupation as well as health behavior such as diet and exercise. The authors converted these data to scores [Diabetes-score (DM-score), Hypertension-score (HT-score), and Dyslipidemia-score (DLP-score)] depending on the frequency of poor behavior. The details of how the scores were calculated were as follows:

Criteria used for the poor behavioral score (DM-score):

1. Frequency of consuming sweets within six months before randomization (10 levels)
2. Frequency of consuming sweetened beverages within six months before randomization (10 levels)
3. Frequency of consuming sticky rice within six months before randomization (10 levels)
4. Frequency of adding sugar to a meal within six months before randomization (10 levels)
5. Frequency of consuming sweet fruits within six months before randomization (10 levels)
6. Frequency of forgetfulness regarding adherence to taking medication within six months before randomization (8 levels)
7. Frequency of exercise within six months before randomization (7 levels)
8. Frequency of consuming vegetables within six months before randomization (10 levels)
9. Frequency of consuming riceberry or brown rice within six months before randomization (10 levels)

Details of the behavioral questionnaire can be found in the supplementary document. A score of 1 indicates that the behavior was not frequent, higher scores indicate an increasing frequency in the behavior, with the maximum score given in brackets next to the item on the list. For desirable behaviors such as exercise and consumption of vegetables and brown rice/riceberry, a score of 1 indicated that the behavior was frequent, higher scores indicate a decreasing frequency. The scores for each behavior were then added and converted to a percentage. A higher score indicates poorer behavior.

For the HT- and DLP-scores, the same principle as the one for the DM-score was used. Details of the questionnaire can be found in the supplementary document.

At the end of the study, the authors reassessed the health behavior and accessibility of messages.

In addition to the questionnaire, medical records from Chaiyaphum Hospital were used to collect patient information such as the time to diagnosis of diabetes, complications from diabetes mellitus, details of the medication used, whether patients self-monitored their blood glucose, any history of diabetic training programs, adjustments to the medication within three months before participation in the study, and the HbA1c, fasting blood glucose, estimated glomerular filtration rate, and lipid profiles.

Intervention

Patients in the messaged group received an infographics message regularly, which was approximately three times a week. The control group did not receive any messages. The infographics-message consisted of easy-to-understand images and videos that aimed to motivate and promote healthy behavior as well as general knowledge of diabetes. Examples of the messages are provided in the supplementary data. Both groups received usual care including adjusting the medication. The primary outcome measures the rate of change in HbA1c levels per visit. Secondary outcome measures included behavioral changes, which were measured by the frequency of a behavior, with 1 point for the lowest frequency, and 10 points for the highest frequency.

Statistical analysis

A sample size of 194 participants (97 per arm) was estimated to be required for providing 80% power of a one-sided type I error at 5% significance level for detecting a clinically meaningful group difference of 0.4% in HbA1c at nine months[23], assuming a standard deviation of 2% for the control group and 1% for the messaged group, with an ANCOVA repeated measure of pre-treatment twice and post-treatment twice.

Statistical analyses were performed using Stata, version 14 (StataCorp LP, College Station, TX, USA). All statistical tests estimated a two-sided error at a 5% significance level. The authors conducted both intention-to-treat and as-treated analyses.

For the outcome measurements, the authors used generalized estimating equations to evaluate the effect of the intervention on HbA1c at three-, six-, and nine-month follow-ups, which were adjusted for gender, age, body mass index (BMI), education level, a history of previous diabetes training in Chaiyaphum Hospital, adjust medicine during the project, and three pre-treatment measurements of baseline HbA1c levels. Furthermore, the authors included an interaction term between the treatment and month. The means, 95% confidence intervals (CIs), and p-values were calculated.

Treatment effect sizes were also compared between important subgroups, including treatment with insulin. For the secondary outcome measures, the frequency of each behavior was converted to a score. The differences between the scores from the beginning and end of the study were calculated for each participant; a t-test was performed to compare the two study groups.

Results

Between February 2018 and March 2019, 165 individuals were recruited for the present study. Of these, 85 were randomly assigned to the messaged group, and 80 were randomly assigned to the conventionally treated control group. The baseline characteristics of the participants are presented in Table 1. The final nine-month follow-up assessment was completed in December 2019. The retention rate in this study was high as only 13 patients (7.8%) were lost to follow-up with nine patients in the messaged group and four patients in the control group.

Primary outcome

In the intention-to-treat analysis, which compares the outcomes between the two groups based on the initial randomization without considering any changes in group allocation, the rate of change in HbA1c per visit after adjusting for gender, age, BMI, and baseline HbA1c was not significantly different between the two groups. The mean difference in the HbA1c change rate was –0.076 (95% CI –0.32 to 0.17, p=0.54) (Table 2).

Subgroup analysis, the authors stratified into two subgroups by insulin treatment. For the patient with insulin treatment, there were no significant differences in the adjusted HbA1c change rate between the groups (–0.002, 95% CI –0.39 to 0.38, p=0.991) (Table 3). However, for the patient without insulin treatment, the message-group had adjusted HbA1c change rate decrease significantly (–0.44, 95% CI –0.79 to –0.1, p=0.012) (Table 4).

In the as-treated analysis, groups were reclassified based on responses to the questionnaire regarding access to information after nine months. If participants reported not reading the messages at all, they were considered part of the non-messaged group. The HbA1c change rate per visit in the group

Table 1. Baseline characteristics

Characteristics	All (165)	Messaged group (85)	Control group (80)	p-value
Sex				0.824
Male (%)	33.33	33.33	34.18 (27/79)	
Female (%)	66.67	67.47	65.82 (52/79)	
Age (years); mean±SD	48.17±13	48.45±13	47.87±13.1	0.776
Body weight (kg); mean±SD	69.36±14	68.89±14.14	69.86±13.93	0.661
Body mass index (kg/m²); mean±SD	26.47±4.71	26.21±4.92	26.75±4.5	0.475
Diabetes details				
Duration of DM (years); mean±SD	7±4.2	7.21±4.59	6.8±3.8	0.55
Type 2 DM (%)	90.28	90.14	90.41	
Type 1 DM (%)	9.72	9.86	9.59	0.956
HbA1C (%); mean±SD	9.74±1.69	9.73±01.65	9.76±1.75	0.93
LDL; mean±SD	105.2±38.35	102.92±36.9	107.52±39.88	0.475
eGFR; mean±SD	95.88±28.25	95.14±29.96	96.59±26.67	0.763
SBP; mean±SD	131.29±16.33	132.77±16.45	129.75±15.95	0.263
DBP; mean±SD	82.04±11.52	83.07±11.68	80.97±11.34	0.272
Scores; mean±SD				
DM-behavior score (baseline)	49.27±11.8	48.56±12.77	49.95±10.82	0.501
HT-behavior score (baseline)	47.36±11.27	45.82±11.3	48.86±11.13	0.122
DLP-behavior score (baseline)	42.19±12.47	42.84±12.42	41.56±12.57	0.56
Income; mean±SD	19,711.95±32,636.17	19,575.18±17,577.89	19,835±42,003.7	0.966
Occupation (%)				0.138
Government officers	26.67	24.56	28.57	
Agriculturist	25.00	29.82	20.63	
Business owner	15.0	21.05	9.52	
Employee	20.0	17.54	22.22	
Freelance	10.83	7.02	14.29	
Student	2.5	0.0	4.76	
Education (%)				0.420
Primary school or lower	29.17	35.09	23.81	
Junior high school	11.67	14.04	9.52	
High school	19.17	14.04	23.81	
Vocational Certificate in Accountancy/Diploma in Accountancy	11.67	12.28	11.11	
Higher education	28.33	24.56	31.75	
Treatment (%)				
SMBG	51.27	46.34	56.58	0.198
With Insulin injection	52.56	54.32	50.67	0.65
Previous diabetic education program	40.41	32	49.3	0.033
Comorbidity (%)				
Hypertension	60.25	57.83	62.82	0.518
Dyslipidemia	67.13	64.79	69.44	0.553
Other	2.8	2.82	2.78	0.989
Smoking	7.5	8.77	6.35	0.615
Complication (%)				
DR	20.98	23.94	18.06	0.387
Stroke	3.5	2.82	4.17	0.660
IHD	3.5	2.82	4.17	0.660
History of CHF	2.1	1.41	2.78	0.568
Adjusted antidiabetic medicine within 3 months before randomization (%)	40.67	45.57	35.21	0.197
Adjust medicine during project (%)	53.79	59.46	47.89	0.162
Decrease insulin during project (%)	12.26	14.1	10.39	0.481

DM=diabetes mellites; HbA1c=hemoglobin A1c; LDL=low density lipoprotein; eGFR=estimated glomerular filtration rate; SBP=systolic blood pressure; DBP=diastolic blood pressure; HT=hypertension; DLP=dyslipidemia; SD=standard deviation; SMBG=self-monitoring blood glucose; DR=diabetic retinopathy; IHD=ischemic heart disease; CHF=congestive heart failure

Data showing baseline characteristics of both groups of participants. The p-values are from the independent t-test or a Wilcoxon signed-rank test.

Table 2. The rate of change in HbA1c per visit (intention-to-treat analysis)

	HbA1c change rate	SE	95% CI		p-value
			LL	UL	
Messaged group	–0.01	0.07	–0.14	0.12	0.880
Control group	–0.05	0.06	–0.17	0.07	0.409
Difference between both the groups	0.04	0.09	–0.14	0.22	0.653

HbA1c=hemoglobin A1c; SE=standard error; CI=confidence interval; LL=lower limit; UL=upper limit

Data show the rate of change in HbA1c per visit (intention-to-treat analysis) in both groups of participants and adjusted mean difference. The p-values are from generalized estimating equations.

Table 3. The rate of change in HbA1c per visit (intention-to-treat analysis,with insulin treatment)

	HbA1c change rate	SE	95% CI		p-value
			LL	UL	
Messaged group	–0.008	0.13	–0.27	0.25	0.950
Control group	–0.006	0.15	–0.29	0.28	0.967
Difference between both the groups	–0.002	0.2	–0.39	0.38	0.991

HbA1c=hemoglobin A1c; SE=standard Error; CI=confidence interval; LL=lower limit; UL=upper limit

Data show the rate of change in HbA1c per visit (intention-to-treat analysis) in both groups of participants and adjusted mean difference. The p-values are from generalized estimating equations.

Table 4. The rate of change in HbA1c per visit (intention-to-treat analysis, without insulin treatment)

	HbA1c change rate	SE	95% CI		p-value
			LL	UL	
Messaged group	–0.67	0.13	–0.93	–0.40	<0.001
Control group	–0.23	0.11	–0.45	–0.002	0.048
Difference between both the groups	–0.44	0.176	–0.79	–0.097	0.012

HbA1c=hemoglobin A1c; SE=standard error; CI=confidence interval; LL=lower limit; UL=upper limit

Data show the rate of change in HbA1c per visit (intention-to-treat analysis) in both groups of participants and adjusted mean difference. The p-values are from generalized estimating equations.

Table 5. The rate of change in HbA1c per visit (as-treated analysis)

	HbA1c change rate	SE	95% CI		p-value
			LL	UL	
Messaged group	–0.23	0.06	–0.35	–0.12	<0.001
Control group	0.01	0.06	–0.12	0.13	0.93
Difference between groups	–0.24	0.09	–0.41	–0.07	0.006

HbA1c=hemoglobin A1c; SE=standard error; CI=confidence interval; LL=lower limit; UL=upper limit

Data show the rate of change in HbA1c per visit (as-treated analysis) in both groups of participants and adjusted mean difference. The p-values are from generalized estimating equations.

that accessed and read the messages regularly was significantly lower than that in the control group after adjusting for possible confounding factors including gender, age, BMI, insulin treatment, baseline HbA1c, and history of adjusting treatment within three months before randomization, with a mean difference of the HbA1c change rate of –0.3 (95% CI –0.37 to –0.23, p<0.001) (Table 5).

Secondary outcome

To compare the effects of the infographic messages on behavior, the authors measured behavioral frequencies. After the intervention, we found a significant decline in the bad-behavioral score, DM-score, and DLP-score (Table 6).

Participant engagement

Only 85 of the 165 patients answered the nine-month follow-up questionnaire. There were 85 randomized participants in the messaged group. Of these, 14 participants could not receive messages due to mobile phone and internet problems. For

Table 6. Change in poor behavior scores (after-before)

Score	Messaged group				Control group				p-value
	Score change	SE	95% CI		Score change	SE	95% CI		
			LL	UL			LL	UL	
DM score	−5.24	1.54	−8.36	−2.13	−0.45	2.0	−4.47	3.5	0.03
HT score	−4.13	1.49	−7.15	−1.13	−2.3	1.94	−6.27	1.58	0.47
DLP score	−6.1	1.34	−9.75	−2.45	−0.29	1.89	−4.12	3.52	0.01

DM=diabetes mellitus; HT=hypertension; DLP=dyslipidemia; SE=standard error; CI=confidence interval; LL=lower limit; UL=upper limit
Data show the change in poor behavior scores (after-before) in both groups of participants.

the messaged group, 44 out of 85 patients (52%) answered the nine-month follow-up questionnaire and 35 of these 44 patients (79.5%) responded that they understood the content of the messages and read them regularly.

Discussion

Educating patients is essential in the treatment of diabetes. However, diabetes education programs are not accessible to all diabetic patients in developing countries. In Chaiyaphum Hospital, diabetes education programs are taught for 60 minutes to most diabetic patients only once after diagnosis. As such, these education programs have not resulted in sustained behavioral changes in the diabetic patients, a consequence of the lack of medical personnel in most government hospitals in Thailand. However, diabetic patients who have completed more than 10 hours of diabetes self-management education over six to nine months have reduce levels of HbA1c and lower mortality rates[(24,25)]. Thus, to save time and medical resources, the solution to diabetes education-related problems requires communication technology that can regularly and simultaneously send messages directly to many patients.

In the present study, the main outcome was comparing the HbA1c change rate between the messaged and control groups. There were no differences in outcomes between the two groups of patients, consistent with a previous study in developing countries[(26)]. The present study included a higher proportion of patients who injected insulin than other positive-outcome trials did and patients with a lower education level and longer diabetes duration than those in the previous studies[(11,27,28)]. The authors believed that these factors influenced the results. As can be seen from the result of subgroup analysis

Subgroup analysis based on insulin treatment status revealed interesting findings. Among patients using insulin treatment, there was no significant difference in adjusted HbA1c change rate between the control and the messaged groups. However, for patients without insulin treatment, the messaged group exhibited a significant decrease in adjusted HbA1c change rate compared to the control group. This suggested that the intervention may have a differential effect based on the use of insulin treatment, with potentially greater benefits observed in patients not requiring insulin.

Regarding the intervention, the present study did not have a complete feedback loop with patients gathering health data and providing feedback nor did it have education via two-way communication, both important factors for success[(29)].

For the main outcome measurement, the authors measured HbA1c levels at three points over nine months and used a regression model to compare between-group differences, however, most studies used a paired t-test over six to nine months[(9,11,13,15-17,27,28)].

In the as-treated analysis, which assessed compliance to infographic messaging via a questionnaire after follow-up, the participants who understood the messages well and read them regularly had better outcomes than those who did not. Therefore, in addition to the content and regularity of the messages, compliance was another key factor for success.

Although the targeted sample size, which was calculated based on a repeated measure for two times before and two times after intervention, was not reached, the actual study measured the treatment outcome (HbA1c) three times before and three times after the intervention. Therefore, when the authors recalculated the required sample sizes, only 65 participants per treatment arm were predicted to be necessary to reach the same statistical power for the treatment.

For the secondary outcome, the authors analyzed the change in bad behavioral scores before and after the intervention. Compared with the control group, the messaged group showed a significant reduction in scores. This suggests that messaging improved and sustained behavior over the nine-month follow-up period, consistent with the previous studies[10-12,28,30]. However, messaging did not reduce HbA1c levels in the intent-to-treat analysis possibly because the behavioral changes were not sufficient or because of patient bias owing to the inability to blind the intervention.

Strength

The present study was the first to examine the utility of infographic messages via chat application in government hospitals in Thailand. Other strengths of the present study include its pragmatic design, use of measurable outcomes that included both HbA1c and the change in the post-intervention behavioral score, and its sample size. Although the targeted sample size, calculated based on a repeated measure for two times before and two times after intervention, was not reached, the actual study measured the treatment outcome (HbA1c) three times before and three times after the intervention. Using the actual measured treatment outcome, the recalculated the required sample sizes required only 65 participants per treatment arm to reach the same statistical power for the treatment.

The strengths of the intervention included the usage of simple low-cost technology, which has been adopted by over 40 million Thai people, regular message sending, and long-term follow-up that enabled testing of the sustained effect of the intervention.

Limitation

The most important study limitation was that the end-treatment questionnaire was conducted poorly due to the lack of research staff and an inadequate system for following-up the participants. In addition, only 51.5% of all participants answered the nine-month questionnaire that assessed the post-intervention behavioral score and compliance with the messaging, which might not be representative of the overall results. Another limitation was that communication by a one-way message might not have sufficiently engaged the attention of the participants.

Applications

As mentioned above, a possible cause of the ineffective HbA1c reduction, and the different results between the intention-to-treat and as-treated-analyses, is that the present study did not have a complete feedback loop[29] or compliance with accessing the message. Therefore, if applied to real practice, this problem should be solved by including two-way communication with patients and providing an incentive to read the message such as a special queue for meeting the physician. However, messaging cannot substitute for a face-to-face education program, but it can help to enhance and sustain the behavioral changes that might reduce HbA1c levels.

The present study provides valuable insights into the effectiveness of infographics messaging via mobile phone applications in improving glycemic control and promoting healthy behaviors among diabetic patients. Healthcare providers and policymakers can use this evidence to inform the development and implementation of similar mobile health interventions aimed at enhancing diabetes self-management and patient outcomes.

The subgroup analysis revealing differential responses to the messaging intervention based on insulin treatment status highlights the importance of tailoring interventions to individual patient needs and characteristics. Healthcare providers can use this information to identify patient subgroups that may benefit most from specific interventions, thereby optimizing resource allocation and improving intervention effectiveness.

The present study underscores the challenges faced by healthcare systems, particularly in developing countries, in providing comprehensive diabetes education and support services due to resource constraints and limited access to trained personnel. Policymakers can use this evidence to advocate for increased investment in healthcare infrastructure, workforce training, and technology-enabled interventions to improve diabetes care delivery and patient outcomes.

The findings emphasize the importance of patient engagement and adherence in mobile health interventions. Healthcare providers can explore strategies to enhance patient engagement, such as incorporating interactive features, personalized content, and behavioral support components into mobile health platforms. By promoting active participation and sustained engagement, interventions can achieve better long-term outcomes and improve patient satisfaction.

The present study contributes to the growing body of evidence supporting the effectiveness of mobile health interventions in chronic disease management. Future research can build upon these findings by investigating novel intervention approaches, exploring mechanisms underlying intervention effects, and evaluating strategies to overcome implementation barriers. By fostering innovation and evidence-based practice, research efforts can drive continuous improvement in diabetic care and healthcare delivery overall.

Conclusion

In summary, while the overall study did not demonstrate a significant improvement in HbA1c levels with the intervention, subgroup analysis revealed promising results among patients without insulin treatment. Additionally, the intervention led to significant improvements in behavioral outcomes. However, challenges related to participant engagement and adherence highlight the complexities of implementing mobile health interventions in real-world settings. Further research addressing these challenges and exploring tailored interventions may enhance the effectiveness of similar interventions in improving diabetic management outcomes.

What is already known on this topic?

Previous studies had shown that mobile phone technology could improve outcomes in diabetic patients. The majority of such technology is text-based messaging. However, most of the studies are still limited to the developed countries.

What does this study add?

This study was done in Chaiyaphum province, Thailand, representing rural communities in developing countries. The result shows that infographic messaging via mobile chat application can improve behavior of diabetic patients in the right direction.

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Authors' contributions

TT conceived and designed the experiments, contributed to the data analysis, and wrote the manuscript. SN and DP retrieved the data and information from the patients. All authors have read and approved the final manuscript.

Conflicts of interest

The authors declare that they do not have any conflict of interest regarding this publication.

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