# Neck Circumference as a Predictor of Obesity and Metabolic Syndrome in Bangladeshi Women with Polycystic Ovary Syndrome

A. B. M. Kamrul-Hasan, Fatema Tuz Zahura Aalpona[1]

Departments of Endocrinology, and [1]Gyne and Obs, Mymensingh Medical College Hospital, Mymensingh, Bangladesh

## Abstract

**Background and Objective:** Researchers have identified neck circumference (NC) as a valuable tool to detect obesity and metabolic syndrome (MS). We conducted this study to define cutoffs of NC to identify obesity, abdominal obesity, and MS in adult women diagnosed with polycystic ovary syndrome (PCOS). **Methods:** Adult women newly diagnosed with PCOS using the revised Rotterdam criteria having NC measure data in a cross-sectional study titled "Biochemical and Hormonal Profile of Patients with Polycystic Ovary Syndrome" were analyzed. **Results:** Finally, 200 women were analyzed; their mean age was 23.3 (±4.9) years, body mass index (BMI) 26.47 (±5.09) kg/m$^2$, NC 34.6 (±3.04) cm, waist circumference (WC) 88.18 (±11.98) cm, and visceral adiposity index (VAI) was 3.31 (±1.37). NC had positive correlations with age, BMI, WC, systolic and diastolic blood pressure, serum triglyceride, VAI, and testosterone levels. NC cutoff 32.75 cm showed 87.3% sensitivity and 74.4% specificity in detecting abdominal obesity (AUC 0.889, $P < 0.001$) and 88.0% sensitivity and 68.0% specificity for diagnosis of overweight/obesity (AUC 0.877, $P < 0.001$). NC 34.25 cm showed 63.0% sensitivity and 64.0% specificity for diagnosis of MS (AUC 0.681, $P < 0.001$). **Conclusion:** Neck circumference may be a simple and convenient tool in assessing obesity, central obesity, and MS in women with PCOS.

**Keywords:** Body mass index, neck circumference, polycystic ovary syndrome, visceral adiposity index, waist circumference

## Introduction

Polycystic ovary syndrome (PCOS) affects 4%–21% of women of reproductive age worldwide and is one of the most common endocrine disorders among them.[1] Although the primary clinical presentations of PCOS are menstrual abnormality and hirsutism, PCOS is associated with a wide range of metabolic and endocrine abnormalities, including insulin resistance (IR), abnormal glucose tolerance (AGT), dyslipidemia, excess weight, and hypertension (HTN).[2]

In general, obesity is widely correlated with cardiometabolic risk and is strongly associated with diabetes, dyslipidemia, and hypertension. Body mass index (BMI) is usually used to assess overweight and obesity, but it does not help distinguish fat and other tissues, such as muscles; BMI also does not account for regional fat distribution. As an index of central obesity, waist circumference (WC) may be a more suitable predictor of health risks related to obesity than BMI. Moreover, measuring

WC may be difficult and inconvenient in some situations, such as severely obese subjects, and affected by abdominal fullness after meals or any causes of abdominal distention like abdominal gases, ascites, and pregnancy. In addition, thick clothing and respiratory movement also affect the accuracy of WC measurements.[3] Neck circumference (NC) is an index of upper-body subcutaneous adipose tissue distribution, and researchers have identified it as an excellent tool to measure overweight and obesity.[3-5] NC is associated

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with cardiometabolic risks beyond that of BMI and WC.[6] Measuring NC is very easy, quick, reliable, and inexpensive. Also, its measurement is convenient and not affected by the factors mentioned above that influence WC measurement.[7]

Researchers have found a close correlation of higher NC with the components of MS, and NC makes a more significant contribution to the variability of metabolic risk factors in women than in men.[8] NC is found to be a good predictive measure of hyperinsulinemia and raised androgens in obese premenopausal women.[9] Studies also found a positive association of NC with IR in women with PCOS.[10] However, data exploring the relationship of NC with other anthropometric measures of obesity and metabolic syndrome in women with PCOS are scarce. We conducted this study to test the usefulness of NC as a marker for obesity and MS in adult women with PCOS and to define cutoffs of NC to identify obesity, abdominal obesity, and MS in them.

## MATERIALS AND METHODS

### Study subjects

We conducted a cross-sectional study titled "Biochemical and Hormonal Profile of Patients with Polycystic Ovary Syndrome" among women newly diagnosed with PCOS attending the endocrinology outpatient department of a tertiary hospital of Bangladesh from July 2017 to December 2019. The institutional review board approved the study protocol; an informed written consent was taken from the study subjects. PCOS was diagnosed using the revised Rotterdam criteria for adults.[11] Neck circumference was measured in a subgroup of the study participants. Initially, we found data of 216 adult women (age ≥18 years) newly diagnosed with PCOS having records of NC measurement. Out of them, 16 were excluded owing to incomplete data entry or having other causes of neck swelling; finally, 200 women were analyzed. Approval from the ethics committee was obtained on 06-July-2017.

### Anthropometric assessment

We measured standing height to within 1 mm without shoes using wall-mounted stadiometers. Bodyweight measurement was done within 0.5 kg using a standard weight measuring device placed on a hard flat surface with light clothing and without shoes. BMI was calculated by dividing weight in kg with the square of height in meters. WC was measured within 1 mm with the subject standing and at the end of a gentle expiration using a plastic tape measure at the midpoint between the costal margin and iliac crest in the mid-axillary line. We measured NC in the midway of the neck, between the mid-cervical spine and mid anterior neck, to within 1 mm, using a nonstretchable plastic tape with the subjects standing upright. We asked the subject to look straight ahead, with shoulders down but not hunched while taking this reading, and cared not to involve the shoulder/neck muscles (trapezius) in the measurement. Subjects with goiter and other causes of neck swelling were further excluded from the study.

### Clinical and laboratory assessment

Blood pressure (BP) was measured by the auscultatory method, using a standard validated aneroid sphygmomanometer, after at least 5 min of rest. HTN and pre-hypertension (pre-HTN) were defined according to the Joint National Committee VII criteria.[12] The oral glucose tolerance test (OGTT) with a 75 g glucose load was done after overnight fasting for at least 8 h. Fasting plasma glucose (FPG) and plasma glucose 2 h after OGTT (PG 2H-OGTT) were measured using a fully automatic biochemistry analyzer (MINDRAY BS-380) by glucose oxidase method. Glycemic status was determined according to the criteria described by the American Diabetes Association.[13] The lipid profile was measured in fasting states using the above analyzer. Metabolic syndrome was diagnosed using the modified National Cholesterol Education Program (NCEP) ATP III diagnostic criteria using the cutoff of 80 cm for diagnosing abdominal obesity.[14] Serum thyroid-stimulating hormone (TSH), total testosterone (TT), and prolactin were measured using radioimmunoassay (RIA) by automated hormone analyzer LB 2111 Multi Crystal Gamma Counter.

### Statistical analysis

We used Statistical Product and Service Solutions (SPSS) for Windows, version 26.0 software (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) for data analysis. The categorical variables were presented as number (%); continuous variables with normal distribution were presented as mean ± standard deviation (SD), and those not following normal distribution were presented as median (interquartile range, IQR). One-way ANOVA, Chi-square test, and Mann-Whitney U tests were performed to compare the variables between different NC-quartiles. Pearson correlation test was used to see the correlations of NC with other variables. Receiver operating characteristic (ROC) curve analysis was used to determine the cutoff values for NC for abdominal obesity, overweight/obesity (BMI ≥23 kg/m²), and metabolic syndrome. $P$ value ≤ 0.05 was considered statistically significant.

## RESULTS

A total of 200 women with PCOS were analyzed. Their mean age was 23.3 (±4.9) years, BMI 26.47 (±5.09) kg/m², NC 34.6 (±3.04) cm, WC 88.18 (±11.98) cm, and visceral adiposity index (VAI) was 3.31 (±1.37). Out of them, 75% were overweight or obese, 78.5% had abdominal obesity, 29.5% had elevated BP (HTN/pre-HTN), 17.5% had AGT, 91% had dyslipidemia, and 50% had MS; 85.5% of them had clinical and/or biochemical hyperandrogenism.

Comparing clinical, anthropometric, metabolic, and hormonal profiles of the study subjects in different quartiles of NC of the women with PCOS is shown in Table 1. Significant differences among the NC-quartiles were observed for BMI, WC, systolic BP, diastolic BP, serum TG levels, VAI, serum prolactin levels, and among the

**Table 1: Characteristics of the study subjects**

| Variables | Neck circumference (cm) | | | | P |
|---|---|---|---|---|---|
| | Quartile-1 28.0-32.4 ($n=49$) | Quartile-2 32.5-33.9 ($n=36$) | Quartile-3 34.0-36.4 ($n=63$) | Quartile-4 36.5-43.0 ($n=52$) | |
| | Mean±SD or Median (IQR) or n (%) | | | | |
| Age (years) | 22.9±4.4 | 22.7±4.0 | 23.3±5.5 | 24.0±5.1 | 0.584 |
| Irregular menstrual cycle | 47 (95.9%) | 35 (97.2%) | 56 (88.9%) | 49 (94.2%) | 0.315 |
| Clinical hyperandrogenism | 44 (89.8%) | 28 (77.8%) | 52 (82.5%) | 41 (78.8%) | 0.416 |
| BMI (kg/m²) | 22.34±3.77 | 24.16±3.49 | 27.58±4.34 | 30.62±4.16 | <0.001 |
| BMI ≥23 kg/m² | 17 (34.7%) | 24 (66.7%) | 57 (90.5%) | 52 (100%) | <0.001 |
| Waist circumference (cm) | 77.3±8.9 | 83.0±7.7 | 91.0±8.6 | 98.6±10.0 | <0.001 |
| Central obesity | 18 (36.7%) | 28 (77.8%) | 59 (93.7%) | 52 (100%) | <0.001 |
| Systolic BP (mm Hg) | 114±11 | 114±12 | 114±10 | 121±12 | 0.002 |
| Diastolic BP (mm Hg) | 74±10 | 75±8 | 77±8 | 79±9 | 0.009 |
| HTN/Pre-HTN | 9 (18.4%) | 11 (30.6%) | 15 (23.8%) | 24 (46.2%) | 0.013 |
| Acanthosis nigricans | 25 (51.0%) | 24 (66.7%) | 53 (81.4%) | 51 (98.1%) | <0.001 |
| FPG (m mol/L) | 4.93±0.81 | 4.84±0.69 | 4.89±1.31 | 5.03±0.96 | 0.830 |
| 2h-OGTT PG (m mol/L) | 6.45±1.80 | 6.40±1.57 | 6.61±2.03 | 6.66±2.10 | 0.897 |
| AGT | 7 (14.3%) | 7 (19.4%) | 11 (17.5%) | 10 (19.2%) | 0.907 |
| Total cholesterol (m mol/L) | 4.41±0.61 | 4.30±0.77 | 4.48±0.87 | 4.47±0.62 | 0.651 |
| LDL-Cholesterol (m mol/L) | 2.67±0.54 | 2.46±0.68 | 2.77±0.75 | 2.59±0.53 | 0.570 |
| HDL-Cholesterol (m mol/L) | 0.98±0.14 | 0.97±0.16 | 0.99±0.16 | 1.02±0.17 | 0.123 |
| Triglyceride (m mol/L) | 1.52±0.36 | 1.56±0.65 | 1.73±0.60 | 1.83±0.71 | 0.038 |
| Dyslipidemia | 44 (89.8%) | 34 (94.4%) | 58 (92.1%) | 46 (88.5%) | 0.776 |
| Metabolic Syndrome | 13 (26.5%) | 14 (38.9%) | 37 (58.7%) | 36 (69.2%) | <0.001 |
| VAI | 2.90±0.84 | 3.09±1.12 | 3.46±1.45 | 3.66±1.70 | 0.023 |
| Total testosterone (ng/mL) | 0.65 (0.35-0.95) | 0.96 (0.48-1.45) | 0.79 (0.55-1.13) | 0.93 (0.59-1.42) | 0.070 |
| Biochemical hyperandrogenism | 6 (12.2%) | 12 (33.3%) | 12 (19.0) | 18 (34.6%) | 0.023 |
| TSH (μIU/mL) | 1.01 (0.67-1.38) | 1.23 (0.78-2.75) | 1.24 (0.74-1.86) | 1.21 (0.76-1.72) | 0.106 |
| Prolactin | 252.5 (198.4-467.5) | 248 (184.6-462.3) | 250.7 (181.4-382.0) | 188.9 (135.0-280.0) | 0.010 |

*P*-value by One-way ANOVA, Chi-square test, and Mann-Whitney U tests, as applicable, BMI=Body mass index; BP=Blood pressure; FPG=Fasting plasma glucose; 2h-OGTT PG=Plasma glucose 2 h after oral glucose tolerance test; AGT=Abnormal glucose tolerance; LDL=Low-density lipoprotein; HDL=High-density lipoprotein; VAI=Visceral adiposity index; TSH=Thyroid-stimulating hormone

frequencies of overweight/obesity, central obesity, HTN/pre-HTN, acanthosis nigricans, AGT, MS, and biochemical hyperandrogenism.

NC had positive correlations with age, BMI, WC, systolic BP, diastolic BP, TG, VAI, and testosterone levels [Table 2].

Receiver operating characteristic (ROC) curve analysis was used to determine the best cutoff values for NC for abdominal obesity, overweight/obesity (BMI ≥23 kg/m²), and metabolic syndrome. NC 32.75 cm showed 87.3% sensitivity and 74.4% specificity in detecting abdominal obesity [AUC 0.889, 95% CI (0.837–0.940), $P < 0.001$] [Figure 1]. NC 32.75 cm had 88.0% sensitivity and 68.0% specificity for diagnosis of overweight/obesity [AUC 0.877, 95% CI (0.826–0.929), $P < 0.001$] [Figure 2]. NC 34.25 cm showed 63.0% sensitivity and 64.0% specificity for diagnosis of metabolic syndrome, whereas NC 32.75 cm had 87.0% sensitivity and 39.0% specificity for that [AUC 00.681, 95% CI (0.608–0.755), $P < 0.001$] [Figure 3]. NC was not found useful in detecting hyperandrogenism [AUC 0.501, 95% CI (0.388–0.614), $P = 0.614$].

## DISCUSSION

Neck circumference is thought to estimate subcutaneous adipose tissue in the upper body.[15] Compared to visceral adipose tissue, upper body subcutaneous fat is a unique fat depot located in a separate compartment. Upper-body subcutaneous fat releases a more significant amount of systemic free fatty acid than visceral fat, particularly in obese individuals, and is lipolytically more active than lower-body adipose tissue. Insulin resistance relates better with subcutaneous truncal fat compared to intraperitoneal fat.[6] Central obesity, particularly high levels of upper-body fat, is associated with adverse metabolic outcomes such as insulin resistance, diabetes, hypertension, and elevated triglycerides compared to lower-body obesity.[16] The lipolytic activity of upper body fat may mediate its hostile relationship with lipid metabolism and glucose homeostasis.[6]

Researchers have identified NC as a reliable predictor of overweight and obesity. In a study conducted among randomly selected subjects visiting some health care facilities in Bangladesh, Qureshi *et al*.[17] observed that NC had a strong and positive correlation with BMI and WC both in
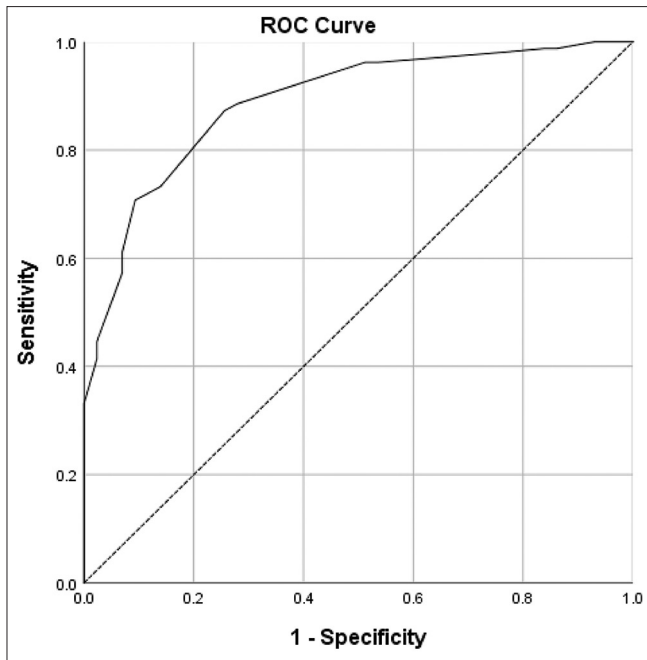
**Figure 1:** ROC curves and area under receiver operating characteristic curves (AUC) for detecting abdominal obesity using neck circumference. [AUC 0.889, 95% CI (0.837–0.940), $P < 0.001$]; [NC 32.75 cm, 87.3% sensitivity and 74.4% specificity]
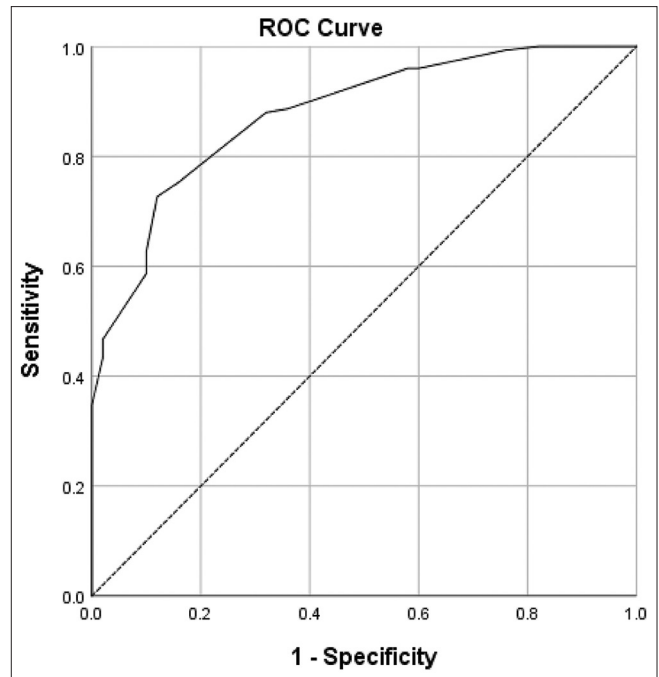


**Figure 2:** ROC curves and AUC for detecting overweight and obesity using neck circumference. [AUC 0.877, 95% CI (0.826–0.929), $P < 0.001$]; [NC 32.75 cm, 88.0% sensitivity and 68.0% specificity]

## Table 2: Correlations of neck circumference (NC) with other variables

| Variables | R | P |
|---|---|---|
| NC and age | 0.167 | 0.018 |
| NC and BMI | 0.675 | <0.001 |
| NC and WC | 0.745 | <0.001 |
| NC and Systolic BP | 0.255 | <0.001 |
| NC and Diastolic BP | 0.252 | <0.001 |
| NC and FPG | 0.036 | 0.614 |
| NC and 2h-OGTT PG | 0.056 | 0.428 |
| NC and Total Cholesterol | 0.066 | 0.354 |
| NC and HDL-Cholesterol | 0.112 | 0.113 |
| NC and LDL-Cholesterol | 0.004 | 0.956 |
| NC and Triglyceride | 0.196 | 0.005 |
| NC and VAI | 0.213 | 0.002 |
| NC and Testosterone | 0.164 | 0.021 |

*P*-value by Pearson correlation test, NC=Neck circumference; BMI=Body mass index; WC=Waist circumference; BP=Blood pressure; FPG=Fasting plasma glucose; 2h-OGTT PG=Plasma glucose 2-h after oral glucose tolerance test; LDL=Low-density lipoprotein; HDL=High-density lipoprotein; VAI=Visceral adiposity index

males and females. NC ≥31.75 cm (AUC 0.62, $P < 0.001$) and ≥34.25 cm (AUC 0.76, $P < 0.001$) in women were the best cutoff values corresponding to overweight (BMI ≥23) and obesity (BMI ≥27.5), respectively. For abdominal obesity, NC ≥31.25 cm (AUC 0.65, $P < 0.001$) was the best cutoff value corresponding to ≥ 80 cm in women. A neck circumference >32 cm in women was the best cutoff point for overweight/obesity in the Pakistani population.[5] In the Indonesian population, females best NC cutoff point indicating overweight/obesity was ≥33.5 cm (sensitivity, 76.6% and specificity, 66.7%).[18] In our study, NC 32.75 cm showed 87.3% sensitivity and 74.4% specificity in detecting abdominal obesity [AUC 0.889, $P < 0.001$]. NC 32.75 cm had 88.0% sensitivity and 68.0% specificity for diagnosis of overweight/obesity [AUC 0.877, $P < 0.001$]. Our observation of the cutoff values to detect overweight/obesity and abdominal obesity in women is higher than those observed by Qureshi *et al*.[17] in the same country. This difference may be due to observer bias and selection bias. Abdominal obesity is considered to be the surrogate marker of insulin resistance. In a study, Chen *et al*.[10] identified that NC 34.25 cm was the best cutoff point for detecting insulin resistance in women with PCOS. Though we did not measure insulin resistance, the cutoff of NC for insulin resistance is higher than that observed for abdominal obesity in our study subjects. The ethnic variations of WC values for defining abdominal obesity may underly this difference. However, NC 34.25 cm was the best cutoff value for metabolic syndrome (63.0% sensitive and 64.0% specific) in the women with PCOS in the current study, which is equal to the cutoff value for insulin resistance described by Chen *et al*.[10] Like Chen *et al*.[10], we observed strong positive correlations of NC with BMI and WC.

Recently, the visceral adiposity index (VAI), a mathematical model that uses simple anthropometric (BMI and WC) and laboratory (TG and HDL-cholesterol) parameters, has been proposed to reflect visceral adiposity and insulin resistance.[19] Increased VAI values were associated with increased cardiometabolic risk in women with PCOS.[20] In the
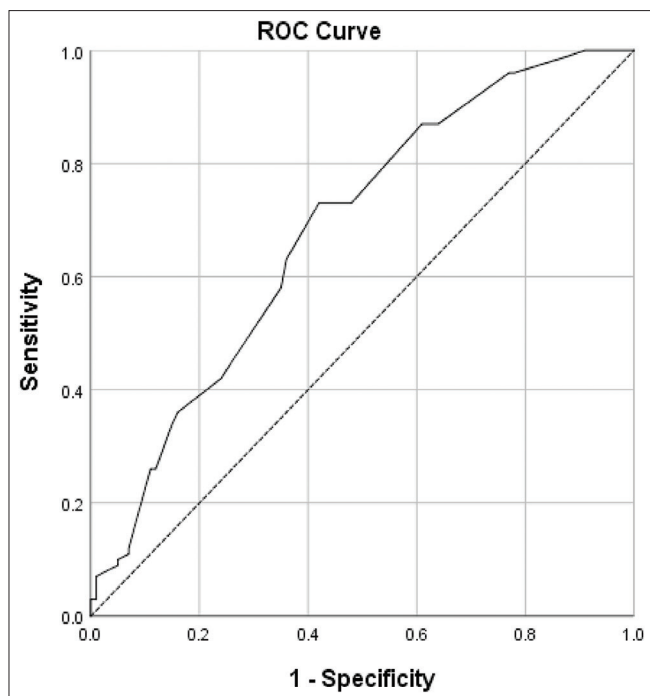
**Figure 3:** ROC curves and AUC for detecting metabolic syndrome using neck circumference. [AUC 0.681, 95% CI (0.608–0.755), $P < 0.001$]; [NC 34.25 cm, 63.0% sensitivity and 64.0% specificity] [NC 32.75 cm, 87.0% sensitivity and 39.0% specificity]

present study, we observed a strong positive correlation of NC with VAI, which further increases the acceptability of NC as a cardiovascular risk marker in PCOS. Dixon et al.[9] observed that the NC is an excellent predictive measure of insulin resistance in obese premenopausal women and a reliable marker of hyperandrogenism in them. We also observed positive correlations of NC with serum total testosterone levels.

The study has several limitations. First, it was a single-center study, and the sample size was small; hence, the result may not be population representative. Second, no comparison group was included in the study. Finally, we did not measure insulin resistance.

## Conclusion

To summarize, we observed strong positive correlations of neck circumference with other parameters of obesity (body mass index, waist circumference) and metabolic syndrome. NC 32.75 cm was the best cutoff value for detecting overweight/obesity, whereas NC 34.25 cm was the best cutoff value for detecting metabolic syndrome. The measurement of NC is simple, time-saving, and more convenient than WC measurement. More data are needed to establish the clinical utility and cutoff values of NC to predict obesity, central obesity, hyperandrogenism, and metabolic syndrome in women with PCOS.

### Acknowledgment

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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