# Costovertebral angle as a novel tool for predicting the thoracic complication risk following percutaneous nephrolithotomy requiring supracostal access

Ahmet Güzel[1]; Taylan Oksay[2]; Sefa Alperen Ozturk[2]; Arap Sedat Soyupek[2]; Alper Ozorak[2], Alim Kosar[2]

[1]Department of Urology, Aydın State Hospital, Aydın, Turkey; [2]Department of Urology, Faculty of Medicine, Suleyman Demirel University, Isparta, Turkey

**Correspondence:** Dr. Ahmet Güzel, Department of Urology, Aydın State Hospital, Aydin, Turkey; drahmetguzel@yahoo.com

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## Abstract

**Introduction:** The objective of this study was to determine whether the costovertebral angle (CVA) and other factors can predict the risk of thoracic complications following percutaneous nephrolithotomy (PCNL).

**Methods:** The data of patients who underwent prone PCNL with supracostal access at Suleyman Demirel University Hospital between January 2015 and December 2019 were retrospectively reviewed. Patients' demographics information (age, sex, body mass index [BMI], stone size, and stone location), operative data (supracostal access site, renal puncture site, and laterality), and postoperative thoracic complications (pleural injury) were evaluated. The CVA was measured on preoperative posteroanterior chest X-ray images. The mean CVA of patients with and without thoracic complications was evaluated.

**Results:** A total of 89 patients (mean age 46.12±15.66 years; 59 men and 30 women) with supracostal access were included in the study. Thoracic complications occurred in 17 (19.1%) patients. Nine (52.9%) hemothorax cases, five (29.4%) pneumothorax cases, and three (17.7%) urinothorax cases were detected. There was a statistically significant difference in the complication rate compared to the percutaneous access site (10th–11th supracostal vs. 11th–12th supracostal) (p=0.004). The mean CVA was significantly lower in patients with complications (45.47±3.59) than in those without complications (53.26±5.98) (p=0.000). No association was found (p>0.05) with age, sex, BMI, laterality, stone surface area, and access site among patients with and without thoracic complications.

**Conclusions:** Preoperative CVA can be an effective tool in predicting the risk of postoperative thoracic complications.

## Introduction

Percutaneous nephrolithotomy (PCNL) is a minimally invasive treatment technique that is recommended as the first step in guidelines for the treatment of kidney stones >20 mm.[1,2] Developments in this technique and technology, which are reflected in its becoming a minimally invasive surgery, has also significantly increased the complication rates.[3] The most frequent complications of PCNL are fever (21%–32.1%), bleeding requiring blood transfusion (11.2%–17.5%), and extravasation (7.2%).[4] However, injuries to adjacent organs have also been reported as complications of PCNL, with pleural injury (0%–3.1%) reported as the most common adjacent organ injury.[4] Hydrothorax, pneumothorax, and hydropneumothorax usually occur following pleural injury during PCNL (especially at the access and dilatation stage), and approximately 64% of patients with pleural injury require chest tube drainage.[5-7] Some clinical symptoms (difficulty with ventilation, shortness of breath, and fever), physical examination findings (decreased breath sounds), and radiographic findings of pleural injury on chest radiographs have been observed in patients with thoracic complications in the acute postoperative period of PCNL.[8]

In the literature, tables, parameters, or nomograms are used to predict the possibility of stone clearance.[9] However, there are no known parameters that can estimate the risk of complications. A study showed that the overall complication rate was 16.3% for supracostal access and 4.5% for subcostal access, regardless of the percutaneous approach.[10] If the thoracic complication rates are compared, only <0.5% of cases punctured below the 12th rib, 3%–15% of cases punctured above the 12th rib, and 10%–100% of cases punctured above the 11th rib developed hydro-/pneumothorax.[10,11] In addition, the role of other factors contributing to complications remains unknown.[11] This retrospective study aimed to evaluate the role of the costovertebral angle (CVA) and other factors in predicting the risk of thoracic complications following PCNL.

## Methods

This study was approved by the Suleyman Demirel University Clinical Research Ethics Committee (approval number: 14/198). The procedures used in this study adhere to the tenets of the Declaration of Helsinki. A total of 1021 patients with nephrolithiasis (645 men, 376 women; mean age, 44.98 ± 16.35 years, range 2–85 years) underwent prone PCNL between January 2015 and December 2019. Of these patients, 89 underwent PCNL with supracostal access, performed by two experienced urologists. In these patients, preoperative, operative, postoperative, and radiological findings were analyzed and compared retrospectively. The patients' demographic information (age, sex, body mass index [BMI], stone size, and stone location), operative data (supracostal access site, renal puncture site, and laterality), and presence of postoperative thoracic complications (pleural injury) were obtained from the

patients' records. The largest axial and coronal diameters were measured separately for the stone size. In patients with multiple stones, stone sizes were calculated separately and the sum of the values was recorded. Staghorn was defined for stones that filled ≥80% of the entire pelvicalyceal system.[12] CVA was defined as the angle of the costovertebral joint between the line passing through the middle of the vertebral column and the line passing through the middle of the 12th rib measured on preoperative standing posteroanterior chest X-ray (CXR) on inspiration (Fig. 1). The CVA of all patients with and without thoracic complications was recorded. All patients who had supracostal access were evaluated using CXR to exclude pneumothorax or hydrothorax immediately after surgery. Pneumothorax was diagnosed based on the displacement of the pleural line in postoperative CXR.[13] However, hydro-/hydropneumothorax was diagnosed if the costophrenic angle and/or the diaphragm were not visible due to fluid density, as detected by postoperative CXR.[14] If hydrothorax was detected, diagnostic thoracentesis was performed to distinguish hemothorax from urinothorax. Patients with thoracic complications and respiratory distress underwent tube thoracostomy, which was then removed when sufficient lung re-expansion was achieved. Asymptomatic patients with thoracic complications were treated conservatively, and no surgical intervention was required as they were clinically stable. Patients who underwent surgery for the ipsilateral kidney, those who underwent PCNL with subcostal access and multiple access points, those with preoperative placement of a nephrostomy tract, those without preoperative posteroanterior CXR images, and pediatric patients were excluded.

### Standard PCNL technique
Under general anesthesia, a suitable calyx was selected for puncture after the contrast agent was injected through the ureteric catheter. One of two methods of percutaneous renal access, namely, triangulation technique or "eye of the needle" technique, was selected.[15] In accordance with published information,[16] access was established under C-arm fluoroscopy during full expiration using an 18-gauge needle while the patient was in the prone position, and the needle was advanced just above the upper limit of the rib to avoid damage to the intercostal vessels. The tract was dilated up to 30 Fr using Amplatz dilatators (Cook Inc., USA). Fragmentation of the stone burden was performed using a pneumatic lithotripter (Vibrolith®, Elmed, Ankara, Turkey). In all cases, 14-Fr nephrostomy catheters (Devon Innovations, UK) were inserted into the renal pelvis or related calyx at the end of the operation. As a last step, nephrostogram was performed to ensure the location of the nephrostomy tube.

### Statistical analysis
For descriptive statistics, frequency tables and cross tables were constructed. For comparisons, data were categorized and the chi square (χ2) test was used. Chi-squared automatic interaction detector (CHAID) analysis, which is a decision tree method, was performed to investigate the effects of all independent variables used in the analysis on complications. IBM SPSS Statistics for Windows version 25 (IBM Corp., Armonk, NY) was used for data analysis, and the level of significance was set at 0.05.

## Results

Patients' demographics and stone characteristics are shown in Table 1. Among the patients who underwent PCNL, 89 (8.7%) underwent PCNL with supracostal access. Thoracic complications occurred in 17 of these patients (19.1%). Although supracostal access was established above the 12th rib in 78 cases, it was established above the 11th rib in 11 cases. With regard to complications, nine (52.9%) hemothorax cases, five (29.4%) pneumothorax cases, and three (17.7%) urinothorax cases were detected. Twelve patients with respiratory distress (Clavien grade IIIA) were treated via intercostal tube drainage under local anesthesia, and the tube was removed when a sufficient degree of lungs re-expansion was achieved. In contrast, five asymptomatic patients with thoracic complications (Clavien grade I) were treated conservatively, and no surgical intervention was required as they were clinically stable. The length of hospital stay ranged from 6 to 20 days in 17 patients with thoracic complications. The median length of hospital stay was 54 h (interquartile range, 51–58). All patients without complications were discharged on the second postoperative day.

Factors associated with thoracic complications are shown in Table 2. A statistical difference was found in complication rates up to the percutaneous access point (10th–11th supracostal versus 11th–12th supracostal) (p = 0.004). Higher thoracic complications rates were noted in cases with access via the 10th–11th intercostal space (54.5%, 6/11) than in cases with access via the 11th–12th intercostal space (14.1%, 11/78) (p = 0.004). The mean CVA was significantly lower in patients with complications (45.47 ± 3.59) than in those without complications (53.26 ± 5.98) (p = 0.000). Moreover, cases with a CVA range of 40°–45° (60.0%, 9/15) experienced thoracic complications, which was significantly higher (p = 0.000) than in cases with CVA of 46°–51° (25.0%, 8/32) and CVA of >51° (0.0%, 0/42). Significantly higher thoracic complication rates (50.0%, 3/6; 46.7%, 7/15) were noted in patients with midpolar and upper pole stone locations than in those with other stone locations (5.9%, 1/17; 11.8%, 6/51) (p = 0.002). No association was found (p > 0.05) with age (46.12 ± 16.30 vs. 46.12 ± 15.63), sex (4 [13.3]/26 [86.7] vs. 13 [22.0]/46 [78]), BMI (26.99 ± 4.87 vs. 25.35 ± 524), laterality (10 [20.0]/40 [80.0] vs. 7 [17.9] vs. 32 [82.1]) stone size (axial, 23.18 ± 8.87 vs. 24.41 ± 8.96; coronal, 18.26 ± 7.48 vs. 18.12 ± 9.10), and renal puncture site between patients with and without thoracic complications.

The results of the CHAID analysis, with estimates of 10.1% risk and 89.9% confidence, are shown in Figure 2. All 11 independent variables were included in the decision tree, and their effects on complication development were analyzed. The variable that had the greatest effect on complication development was CVA ($\chi^2$ = 26.875 df = 2, p = 0.000). The model divided all angle groups into separate nodes, and the development of complications varied in all angle groups. According to the model, cases with the highest risk of complications were those with CVA of 40°–45° (60.0%). Patients with CVA of 46°–51° followed those with CVA of 40°–45°, and the risk of complications was 25.0%. Patients with CVA of >51° were not at risk of developing complications. When the CVA was 46°–51°, the model showed the supracostal access site as a second factor. When the CVA was 46°–51° and the supracostal access site was the 10th–11th intercostal space, all patients developed

complications, and when the supracostal access site was the 11th–12th intercostal space, 11.1% of the patients developed complications.

**Discussion**

In this study, we revealed for the first time a relationship between the CVA and the risk of thoracic complications. However, we showed that the risk of thoracic complications decreases as the CVA increases.

The actual incidence of pleural injury remains unknown because in most cases it is not noticeable as the injury is clinically insignificant.[14,17] The majority of pleural injuries heal spontaneously over time. Sofer et al. evaluated non-contrast computed tomography (CT) findings of 100 patients who underwent PCNL and found no correlation between those diagnosed with pleural effusion with CT and clinical pleural effusions.[17] CXR is the first-line imaging method recommended for the detection of thoracic complications. Therefore, CXR was performed to identify thoracic complications in the postoperative period in patients with supracostal access, regardless of the presence or absence of clinical symptoms (e.g., difficulty in ventilation and shortness of breath) and physical examination findings.[8,13]

Anatomically, the parietal pleura crosses the middle of the 12th rib posteriorly and the 11th rib at the posterior axillary line.[18] A safe zone is present on the lateral side of the intersection between the 11th intercostal space and the middle scapular line, which minimizes the risk of pleural injury.[18] Therefore, due to the fact that we established supracostal access by puncturing the skin and subcutaneous tissues during expiration and the renal parenchyma during inspiration from the safe area described above, we believe that the risk of thoracic complications is reduced and that our supracostal access is as safe as infracostal access. In all cases, we established PCNL intercostal access by puncturing the skin and subcutaneous tissue during expiration and the renal parenchyma during inspiration. Nevertheless, pleural complications occurred in 19.1% of the patients with supracostal access. The incidence of thoracic complications in patients with supracostal access was similar to that reported in the literature.[10,19,20] However, the thoracic complication rate was higher in cases with 10th–11th intercostal access than in those with 11th–12th intercostal access and was similar to that reported by Munver et al.[10] and Sinha et al.[20]

In our opinion, the higher thoracic complication rate in the 10th–11th intercostal access could be attributed to the anatomical course of the parietal pleura and diaphragm in the thorax, considering that even if the puncture was performed during expiration, the parietal pleura and diaphragm may come in the path of the needle. However, in the prone position, the lung may fill the posterior costodiaphragmatic recess even below the 12th rib.[21] Therefore, PCNL carries a risk of pleural complications, and understandably, the risk increases as the supracostal access site is higher. For this reason, we thought that CVA could be important in predicting the risk of thoracic complications.

To the best of our knowledge, no study has examined the relationship between CVA and thoracic complications in PCNL. The mean CVA of patients with thoracic complications was significantly lower than that of patients without thoracic complications ($p = 0.000$). In particular, the thoracic complication rate was higher in patients with CVA of 40°–45° (60.0%,

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9/15); however, the complication rate decreased to 25% (8/32) in patients with CVA of 46°–51°. Thoracic complications were not observed in patients with CVA of >51° (0.0%, 0/42). We think that as CVA increases, the 12th rib and diaphragm are elevated. This elevation brings the costal and diaphragmatic pleura closer, causing the costodiaphragmatic recess to close. Therefore, we considered that the incidence of thoracic complications was reduced with increased CVA.

Patients who had upper pole and midpolar stone locations had significantly higher thoracic complications than those with other stone locations (p = 0.002). Studies have shown that the percutaneous access site rises as the stone localization increases and that stone localization is effective in determining the percutaneous access site.[11,19,22] Therefore, we think that this situation causes the percutaneous access site to rise and consequently explains why the thoracic complication rates in our study are higher in stones with upper and middle pole locations.

Studies have shown significant difference in age, BMI, and laterality among those with and without thoracic complications after PCNL.[11,23-25] However, this was not true in our study because no significant difference was found between patients with and without thoracic complications in terms of age, sex, BMI, laterality, and stone size. The absence of significant difference in BMI is thought to be due to the low BMI variability in our study, so we feel that higher BMI variability would have uncovered an association between BMI and thoracic complications.

Moreover, no association was found with renal puncture site between patients with and without thoracic complications (p > 0.05). Similar conclusions were also made by Singh et al., who did not find a significant difference between the groups in terms of thoracic complications in 94 patients who were grouped by upper calix and lower calix entry points.[18] With regard to the development of thoracic complications, it is not important where the renal parenchyma is punctured from, but where the access was established to the skin and subcutaneous tissue up to the kidney are important.

The ideal puncture has been described as one that provides the shortest and straightest access to all calculi; avoids major vessels, bowels, and lung; lies along the axis of the calyx; and causes minimal parenchymal damage.[20] However, the ideal puncture should be in a straight line traversing the shortest distance from the skin to the infundibulum. Thus, it is important to identify conditions that will prevent complications as well as ideal puncture conditions. In most cases, we plan to reach the stone with a subcostal access preoperatively as described above, but in some cases, we had to perform supracostal access because the planned route could not be used intraoperatively due to the patient's body structure or kidney movements.

In this study, PCNL was performed under fluoroscopy guidance. Studies have reported that the incidence of adjacent organ injury in ultrasound-guided PCNL is less than that in fluoroscopy-guided PCNL.[26,27] Li et al reported that 0.19% of 8025 patients who underwent ultrasound-guided PCNL with subcostal access had a pleural injury.[28] In addition, Ng et al. reported that 72 patients who underwent ultrasound-guided PCNL with subcostal access had no pleural injury.[26] This condition is thought to be mainly due to the ability of ultrasound to

provide information about the surrounding viscera and the depth of puncture needle penetration. Therefore, to prevent thoracic complications, especially in patients with narrow CVA, ultrasound-guided PCNL with subcostal access may be a more appropriate and a better choice than PCNL with supracostal access under fluoroscopy.

At present, similar to other surgeries, certain nomograms have important roles in predicting complications and surgical success after PCNL. These nomograms allow the surgeon to define possible postoperative and preoperative complications, as well as the surgical success, and enable them to share these opinions with their patients.[9,16,29] Based on this, we considered the question, "Can we predict thoracic complications that may develop during surgery by measuring CVA from preoperative CXR of patients before PCNL?" As a result of the CHAID analysis, CVA was shown to have the greatest effect on complication development. According to the model, as the CVA increases, the risk of thoracic complications decreases. Cases with CVA of >51° had no risk of complications. Based on these results, we consider that we may predict possible thoracic complications with 10.1% risk and 89.9% confidence by evaluating preoperative CVA of patients.

This study had several limitations. This was not a randomized, prospective study but a retrospective analysis of 89 patients who underwent PCNL with supracostal access. To the best of our knowledge, there is no information on the relationship between CVA and thoracic complications in PCNL. Therefore, one of the strengths of this study is that it shows that possible thoracic complications can be predicted by evaluating preoperative CVA. The limitations discussed above can be eliminated by conducting multicenter prospective studies with a larger number of patients in the future, and nomograms can be created to predict the risk of thoracic complications.

## Conclusions

The results showed that preoperative CVA measured using CXR, and supracostal puncture localization is an important indicator for predicting the risk of thoracic complications in PCNL. In particular, CVA <51° in cases with supracostal access is a warning sign for thoracic complications in prone PCNL. Although this study was retrospective and was conducted at a single center, the evidence suggests that we should be watchful of thoracic complications in this patient group; thus, postoperative evaluation for thoracic complications should be made mandatory.

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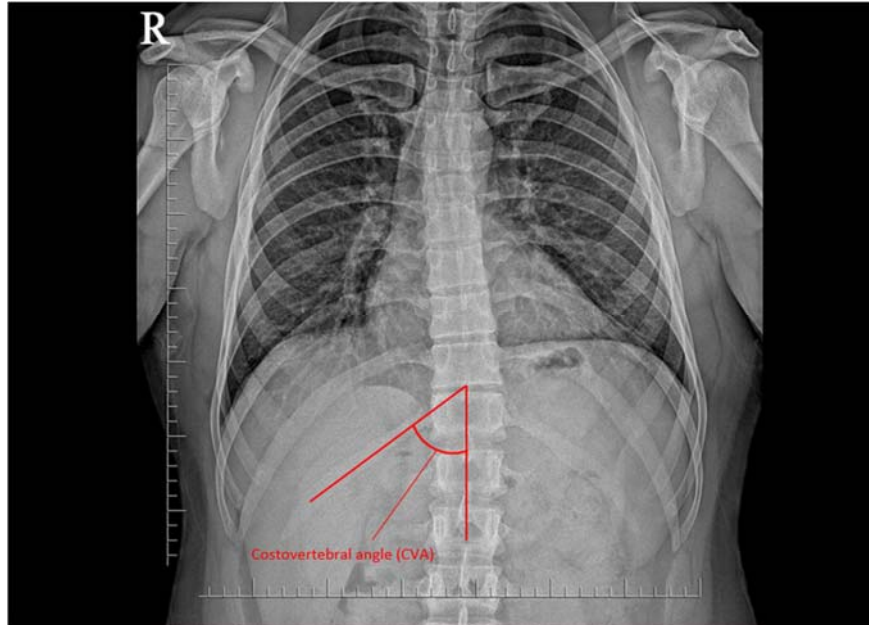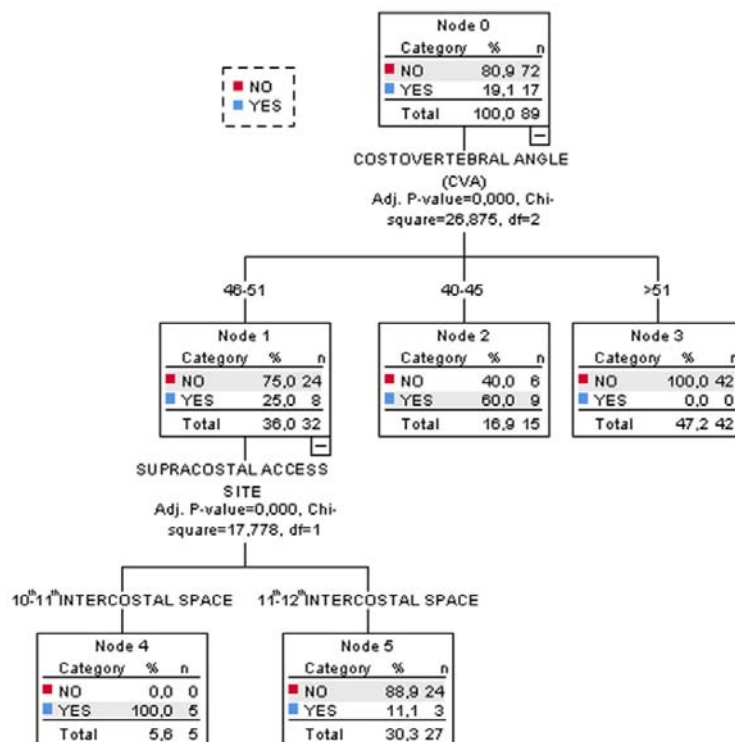
## Figures and Tables

*Fig. 1.* The costovertebral angle, defined as the angle between the 12th rib and vertebrae.



*Fig. 2.* CHAID analysis (decision tree method), which enables the determination of the effect level of variables on the development of complications.

| Table 1. Baseline patient characteristics | |
|---|---|
| **Characteristic** | |
| Age (years), mean ± SD | 46.12±15.66 |
| Sex, n (%) | |
|   Female | 30 (33.7) |
|   Male | 59 (66.3) |
| Body mass index (kg/m$^2$), mean ± SD | 26.68±4.95 |
| Laterality, n (%) | |
|   Right | 50 (56.2) |
|   Left | 39 (43.8) |
| Thoracic complications, Yes/No, n (%) | 17 (19.1)/72 (80.9) |
| Costovertebral angle (degree), mean ± SD | |
|   With thoracic complications | 45.47±3.59 |
|   Without thoracic complications | 53.26±5.98 |
| Stone characteristics, n (%) | |
|   Staghorn | 7 (7.9) |
|   Multiple/pelvic/single calyceal | 82 (92.1) |
| Mean stone surface area (mm$^2$), mean ± SD | 510.49±433.85 |

SD: standard deviation.

| Table 2. Factors (stone, renal, and operative) associated with development of pleural injury | | | |
|---|---|---|---|
| | **Thoracic complications** | | |
| | **With thoracic complications (n=17)** | **Without thoracic complications (n=72)** | **p** |
| Laterality (%) | | | $\chi^2$=0.060, df=1, p=0.807 |
| Right | 10 (20.0) | 40 (80.0) | |
| Left | 7 (17.9) | 32 (82.1) | |
| Stone location (%) | | | $\chi^2$=14.782, df=3, p=0.002 |
| Upper pole | 7 (46.7) | 8 (53.3) | |
| Midpolar | 3 (50.0) | 3 (50.0) | |
| Lower pole | 1 (5.9) | 16 (94.1) | |
| Kidney pelvis | 6 (11.8) | 45(88.2) | |
| Renal puncture site (%) | | | $\chi^2$=6.403, df=3, p=0.094 |
| Upper calyx | 5 (13.5) | 32 (86.5) | |
| Midpolar calyx | 8 (19.5) | 33 (80.5) | |
| Lower calyx | 4 (50.0) | 4 (50.0) | |
| Posterior calyx | 0 (0.0) | 3 (100.0) | |
| Supracostal access site (%) | | | $\chi^2$=10.892, df=2, p=0004 |
| 11th–12th intercostal space | 11 (14.1) | 67 (85.9) | |
| 10th–11th intercostal space | 6 (54.5) | 5 (45.5) | |
| Costovertebral angle (%) | | | $\chi^2$=26.875, df=2, p=0.000 |
| 40°–45° | 9 (60.0) | 6 (40.0) | |
| 46°–51° | 8 (25.0) | 24 (75.0) | |
| >51° | 0 (0.0) | 42 (100.0) | |
| Mean stone surface area (mm$^2$), mean ± SD | 629.02±594.00 | 482.50±386.90 | p=0.213 |
| Age | 46.12±16.30 | 46.12±15.63 | $\chi^2$=8.347, df=7, p=0.303 |
| Sex | | | $\chi^2$=0.974, df=1, p=0.324 |
| Female | 4 (13.3) | 26 (86.7) | |
| Male | 13 (22.0) | 46 (78) | |
| Body mass index (kg/m$^2$), mean ± SD | 26.99±4.87 | 25.35±5.24 | $\chi^2$=1.712, df=3, p=0.634 |

SD: standard deviation.