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ARTICLE

# Electrocardiographic changes after breast reduction surgery

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**ABSTRACT**

Macromastia is associated with symptoms related to postural changes and decreased mobility. Breast reduction surgery (BRS) is the treatment of choice for these patients. Anatomical and structural changes in body posture and habitus might cause changes in electrocardiography (ECG). In this study, we aimed to evaluate the outcome of BRS on ECG changes of the patients after surgery. Study population included 33 female patients who had undergone BRS. ECG records of every patient before procedure and 6 months after procedure were analyzed retrospectively. Patients were naïve of known cardiac diseases and the patients did not have any known arrhythmia. The mean age of the study population was 40.8 ± 9.6. Total removed breast tissue from both sides was 1493 (1052–2138) mL, as 800 (513–1093) mL removed from right side and 740 (519–1050) mL removed from left side. There were significant changes in ECG of the patients in post-operative period. Atrial conduction parameters such as, PR duration ($p<.001$), Pmax duration ($p<.001$) and P wave dispersion ($p<.001$) were significantly decreased post-operatively. Additionally, ventricular conduction parameters such as, TPe duration ($p<.001$), TPe/QT ($p=.013$) and TPe/QTc ($p=.005$) ratios were found significantly decreased in ECGs of the patients. BRS as a treatment for macromastia does not only improve posture and mobility of the patients and also have positive impact on cardiac conductions. In patients those had BRS, atrial and ventricular conductions detected by ECG recordings were improved after surgery.

**Abbreviations:** BRS: breast reduction surgery; ECG: electrocardiography; Pmin: minimum duration of P wave; Pmax: maximum duration of P wave; PWD: P wave dispersion; QTc: corrected QT interval; SD: standart deviation

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## Introduction

Macromastia is a clinical condition that is mostly associated with symptoms related to postural changes and decreased mobility. Breast reduction surgery (BRS) is the method of choice in treating patients with macromastia. The procedure might be performed for postural improvement and aesthetic purposes. The outcome of BRS on quality of life and posture is well known [1,2]. BRS might also improve pulmonary functions of the patients and additionally the improvement correlates with weight of resected specimen [3,4].

Electrocardiography (ECG) is a diagnostic method that is used to evaluate atrial and ventricular conductions in daily clinical practice. Anatomical and structural changes in body posture such as pectus excavatum and obesity or change of body position might cause ECG modifications even without any cardiac disease [5–7]. It was shown that after bariatric surgery, following weight loss, ECG alterations associated with obesity might reverse [8].

Therefore, in this study, we aimed to compare the ECG changes after BRS and evaluate the outcome of BRS on ECG changes of the patients after surgery.

## Materials and methods

### *Study population*

We have reviewed the database of hospital records and retrieved the patients who had undergone BRS due to macromastia and who have ECG in the records pre- and post-operatively, retrospectively. Study population included 33 female patients who had undergone BRS between the time period of January 2011 to January 2021 at a tertiary training and research hospital. The patients, who did not have ECG for the time period of pre-operatively and post-operatively in their records, were not included in the study. All patients were over 18 years old. Exclusion criteria were: patients with diagnosis of hypertension, coronary artery disease, history of coronary intervention or coronary artery bypass surgery, known moderate to severe valvular heart disease, pulmonary hypertension, heart failure with reduced or preserved ejection. Patients who had diagnosis those might cause changes in ECG were excluded from the study such as patients who had chronic kidney disease or with electrolyte imbalance or were on dialysis. Patients with atrial dysrhythmia such as patients who had atrial fibrillation or flutter, pre-excitation syndrome, and patients with junctional rhythm or patients with history of pacemaker implantation were not included in the study. Patients who were under treatment of type I and III antiarrhythmic drugs those might interfere with ECG recording were also excluded from the study. Additionally, patients who had unsuitable ECG for evaluation were not included to the study group.

Blood electrolytes were retrieved from the database of the hospital and pre-operative and post-operative levels of these electrolytes were noted. The levels of blood electrolytes were

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retrieved and noted on the same day as the pre- and post-operative ECG recordings were done.

### *Breast reduction surgery*

Surgical procedural and pre-procedural information were recorded. This information included removed volume of the breast tissue for each side and the total removed volume for every patient. Additionally, the surgical technique, which used during removal of the breast tissue, was recorded. During BRS, there are two important points to be considered. First one is the pedicle that gives blood supply to the nipple and second one is the removed volume size to shape the breast properly. The technique depends on the prior factors.

### *Electrocardiography*

In routine clinical practice in our hospital, 12-leads Surface ECG (Nihon Kohden Corporation, Cardiofax M Model ECG-1250, Tokyo, Japan) were recorded pre-operatively during pre-anesthetic visit for every patient. The recordings were performed in the supine position, with a 25-mm/s paper speed and a voltage of 10 mm/s for each patient. ECG records of every patient before the procedure and 6 months after the procedure were analyzed. Two-trained cardiologist (A.A.S. and A.R.D.) reviewed standard 12-lead ECG recordings via using the software of Adobe Photoshop (Adobe Systems, Inc., San Jose, California, United States of America) with appropriate magnification after scanning the recorded ECGs to the computer system. All parameters were measured for two consecutive cycles and then the average values were noted. Heart rate, pre- and post-operative rhythm were noted for every patient. ECG recordings automatically provided P, QRS and T wave axis and durations; however, cardiologists re-analyzed and manually calculated these findings in ECG and were noted. PR interval was measured and recorded for each patient. For each lead, P-wave durations including minimum duration of P wave (Pmin), maximum duration of P wave (Pmax) and P wave dispersion (PWD) were measured according to previous studies [9]. Pmax and Pmin were analyzed in one of the measured leads. PWD was defined and calculated as the difference between Pmax and Pmin duration. QT interval is defined as the distance between the Q wave and T wave and QT interval measured from the first deflection of the QRS complex and to the point of return of the T wave to isoelectric line. Bazett's formula ($QTc = QT/\sqrt{RR}$ interval) was used to calculate the corrected QT (QTc) as described previously [10]. TPe interval defined and measured as the distance between the peak and the end of the T wave. The end of the T wave was delineated as intersection point of the tangent of the downslope T wave and isoelectric line in ECG. TPe interval was assessed only in the precordial leads, whereas QT interval was measured in as many of the 12-leads as possible. TPe and QT ratio (TPe/QT) and TPe and QTc ratio (TPe/QTc) were calculated and evaluated from the findings of related waves and measurements. The inter-observer and intra-observer coefficients of variation were 2.4% and 2.5%, respectively.

### *Statistical analysis*

Statistical analyses were performed using the SPSS version 24.0 (SPSS Inc., Chicago, IL). Whether the variables show normal distribution; visual (histograms, probability curves) and analytical methods (Kolmogorov–Smirnov and Shapiro–Wilk) were evaluated. Numerical variables showing normal distribution were mean ± standard deviation (SD), numerical variables not showing normal distribution were expressed as median (interquartile range) and categorical variables as percentage (%). Chi square or Fisher's exact test were used to compare categorical variables in between groups. Since the distributions of the differences in the dependent variables (ECG parameters) were non-normally distributed, the Wilcoxon signed-rank test was used to assess the changes in ECG parameters. The distribution of differences between the parameters of ECG was assessed using histogram pilots to ensure they were symmetrical in shape since the Wilcoxon signed-rank test requires dependent variables with symmetrical distribution. McNemar's test was used to compare the differences in categorical variables. Throughout the present study, a $p$ value of $<.05$ was considered significant.

**Table 1.** Clinical and operational characteristics of the study population.

| | |
|---|---|
| Age, years | 40.8 ± 9.6 |
| Female gender, *n* % | 33 (100%) |
| Removed volume of breast tissue (right sided), mL | 800 (513–1093) |
| Removed volume of breast tissue (left sided), mL | 740 (519–1050) |
| Total removed volume of breast tissue, mL | 1493 (1052–2138) |
| Operation technique, *n* % | |
| Inverted-T scar with superior pedicle | 6 (18.2%) |
| Inverted-T scar with superomedial pedicle | 6 (18.2%) |
| Vertical scar with superior pedicle | 3 (9.1%) |
| Vertical scar with superomedial pedicle | 2 (6.1%) |
| Inverted-T scar with medial pedicle | 4 (12.1%) |
| Inverted-T scar with free nipple graft | 4 (12.1%) |
| Inverted-T scar with inferior pedicle | 8 (24.2%) |

## Results

In our study, there were 33 female patients who underwent BRS. The mean age of the study population was 40.8 ± 9.6. Table 1 provides information about the clinical characteristics and surgical characteristics of the study population. Total removed breast tissue from both sides were 1493 (1052–2138) mL, as 800 (513–1093) mL removed from the right side and 740 (519–1050) mL removed from the left side. As mentioned above, depending on the aforementioned factors, the surgical techniques were noted and most commonly used surgical technique was inverted-T scar with inferior pedicle and vertical scar with superomedial pedicle technique was the least used one.

Table 2 provides information about ECG parameters and levels of blood electrolytes of the study population. The table shows ECG parameters as comparison between pre-operative and post-operative. There was no significant difference in terms of heart rate ($p=.757$), P wave axis ($p=.955$), QRS wave axis ($p=.117$), T wave axis ($p=.673$), Pmin duration ($p=.517$), QRS duration ($p=.228$), QT interval duration ($p=.320$) and QTc duration ($p=.721$). However, there were significant decreases in PR duration (pre-operative; 160 (151–167) ms vs. post-operative; 152 (142–160) ms, $p<.001$), Pmax duration (pre-operative; 92 (86–95) ms vs. post-operative; 82 (80–86) ms, $p<.001$) and PWD (pre-operative; 22 (20–26) ms vs. post-operative; 17 (15–20) ms, $p<.001$) when compared between pre- and post-operative ECGs. Additionally, TPe duration (pre-operative; 82 (75–85) ms vs. post-operative; 75 (69–80) ms, $p<.001$) was found significantly decreased in post-operative ECGs and related to that there were significant decreases in TPe/QT (pre-operative; 0.221 (0.206–0.231) vs. post-operative; 0.202 (0.184–0.224), $p=.013$) and TPe/QTc (pre-operative; 0.198 (0.184–0.210) vs. post-operative; 0.180 (0.164–0.193), $p=.005$) ratios.

The information about pre- and post-operative levels of blood electrolytes including sodium, chloride, calcium, magnesium and

Table 2. Preoperative and postoperative electrocardiographic and blood electrolytes findings of the study population.

| N = 33 | Pre-operative | Post-operative | p Value |
|---|---|---|---|
| Heart rate, /min | 73 (70–81) | 75 (69–82) | .757 |
| P wave axis, ° | 45 (40–56) | 45 (39–57) | .955 |
| QRS wave axis, ° | 42 (18–49) | 32 (−3–45) | .117 |
| T wave axis, ° | 30 (18–45) | 32 (16–45) | .673 |
| PR duration, ms | 160 (151–167) | 152 (142–160) | **<.001** |
| Minimum P wave duration, ms | 66 (64–71) | 65 (61–70) | .517 |
| Maximum P wave duration, ms | 92 (86–95) | 82 (80–86) | **<.001** |
| P wave dispersion | 22 (20–26) | 17 (15–20) | **<.001** |
| QRS duration, ms | 82 (78–88) | 80 (77–87) | .228 |
| QT duration, ms | 367 (360–385) | 360 (351–388) | .320 |
| QTc duration, ms | 410 (397–425) | 418 (398–430) | .721 |
| TPe duration, ms | 82 (75–85) | 75 (69–80) | **<.001** |
| TPe/QT ratio | 0.221 (0.206–0.231) | 0.202 (0.184–0.224) | **.013** |
| TPe/QTc ratio | 0.198 (0.184–0.210) | 0.180 (0.164–0.193) | **.003** |
| Sodium, mmol/L | 140 (139–143) | 140 (139–141) | .392 |
| Chloride, mmol/L | 102 (99–104) | 101 (100–103) | .718 |
| Calcium, mg/dL | 9.2 (9.0–9.4) | 9.2 (9.1–9.5) | .598 |
| Magnesium, mg/dL | 2.0 (1.9–2.2) | 2.0 (1.9–2.2) | .882 |
| Potassium, mmol/L | 3.9 (3.7–4.2) | 4.0 (3.8–4.2) | .886 |

A $p$ value of $<0.05$ was considered as significant.

potassium is provided in Table 2. There was no significant difference in terms of blood electrolytes before and after surgery in patient group.

## Discussion

In our study, we have evaluated the ECG records of the patients who had BRS and compared the ECG records before and after the BRS. Our aim was to evaluate the effect of BRS on ECG after the surgery. Our study demonstrated that after BRS, atrial conduction parameters including PR duration, Pmax duration and PWD were significantly decreased. Additionally, parameters providing information about ventricular repolarization such as TPe duration, TPe to QT ratio and TPe to QTc ratio were also found significantly decreased after the BRS.

This study is conducted because it is well-known that thoracic surgeries or bariatric surgeries might cause electrocardiographic changes after the surgery due to habitual or positional changes in thorax [11,12]. Additionally, we know that BRS increases pulmonary function in post-operative period and pulmonary functions are closely related with ECG [13–15]. However, there is no study that examined the effect of BRS on ECG after the surgery; therefore, it is of vast importance to recognize if BRS might affect the ECG records.

In literature, the relationship between atrial conduction and PWD was demonstrated in previous researches. Dilaveris et al. [16] compared patients with a history of paroxysmal atrial fibrillation to healthy controls and their study showed that paroxysmal atrial fibrillation patients had higher PWD than healthy controls. According to the studies in literature, Centurión commented that PWD was associated with an abnormality in atrial conduction, and increased PWD might lead to AF shortly [17]. In another study, patients with atrial fibrillation had similarities with patients who had PR interval prolongation and therefore, the authors commented that prolongation in PR interval might be considered as a preliminary stage to atrial fibrillation [18]. Additionally in a meta-analysis, Cheng et al. [19] concluded that, PR interval prolongation should not be considered as a benign condition but an independent risk factor for atrial fibrillation and atrial arrhythmogenesis. On the other hand, the parameters such as TPe duration, TPe/QT ratio and TPe/QTc ratio are used in the evaluation of ventricular repolarization and ventricular arrhythmogenesis [20,21]. Therefore, the improvement is these parameters might be a sign of decreased ventricular arrhythmogenesis and marker of improved ventricular conduction.

In a study, it was found that breast implants might interpret the ECG readings, thus the records might mislead the clinician [22]. In this study, the major limitation was high inter-observer variability between the reviewers of the ECGs. In another study, Kramer et al. found that breast reconstruction surgery employing with tissue expanders did not interfere with the ECG recordings [23]. In this study, all patients had breast cancer and reconstruction surgeries performed because of their malignant pathology. Cancer and related therapies such as radiotherapy or chemotherapy might themselves affect the ECG recordings. Our study is unique that only evaluates the ECG recordings after BRS without any additional pathologies such as cancer or any other systemic disease and specifically inspects the affect of surgery and thoracic changes after the surgery in ECG recordings. Another important point of our study was the patient population that only included patients who had BRS with the indication for habitual or postural changes in the patients and not for aesthetical purposes that indeed might directly indicate the findings related to thoracic postural changes after the surgeries. According to present knowledge, improvement in atrial and ventricular conduction is associated with decreased arrhythmogenesis in cardiac conduction. Therefore, in our study, we believe that these changes occurred due to the improved posture and habitus of the patients and increased pulmonary functions after BRS.

## Study limitations

There are limitations in our study. First, because parameters were identified retrospectively, this study included limitations inherent in any retrospective analysis. Second, we have limited number of patients in the study but increased number of patients might increase the value of the study. Third, we did not follow up the patients in long term to evaluate outcomes of ECG findings in long term for the occurrence of arrhythmias. Fourth, we do not have Holter's monitoring of the patients and it would be valuable to have at least 24-h Holter monitoring in post-operative period to evaluate atrioventricular arrhythmias.

## Conclusions

In our study, we determined that after BRS, parameters related to atrial conduction and ventricular repolarization were improved. Therefore, BRS not only improves the habitus and posture of the patients, additionally, BRS might lead to improvement in cardiac conduction and decreased arrhythmogenesis in post-operative period.

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*Ethical statement and consent to participate*: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
*Informed consent*: The patients signed an informed consent form.

## Disclosure statement

Authors have no conflict of interest. All authors have read and approved the manuscript.

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## Data availability statement

The data supporting our findings can be found in the article. Given the strict regulations of our institutional review board, further data of the patients only available from the corresponding author on reasonable request.

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