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Research article

# Comparison of comfort between cone beam breast computed tomography and digital mammography

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ABSTRACT

*Purpose:* To compare the comfort levels of cone beam breast computed tomography (CBBCT) and digital mammography.

*Materials and methods:* On 409 patients, CBBCT was performed within 1 week after conventional mammography. Patients evaluated their comfort by using an 11-point numerical rating scale (NRS-11) after completing the two examinations. The lower the score was, the more comfortable the examination modality was. The data was divided into different groups according to CBBCT scan mode (non-contrast mode, contrast-enhanced mode), age (≤44, 45～59 and ≥60), body mass index (BMI) (< 18.5 kg/m$^2$, 18.5～23.9 kg/m$^2$, 24～27.9 kg/m$^2$ and ≥28 kg/m$^2$), and breast density (fatty-breast, dense-breast) to evaluate the performance of CBBCT comfort in different groups and to analyse the influencing factor of patient comfort. The paired rank sum test was used to compare the comfort between CBBCT and mammography.

*Results:* Overall, the comfort of CBBCT was better than mammography ($P < 0.05$). CBBCT was more comfortable than mammography in both non-contrast and contrast-enhanced groups ($P < 0.05$). CBBCT was more comfortable than mammography in the ≤44, 45～59 age groups ($P < 0.05$). There was no significant difference in the ≥60 age group ($P = 0.5433$). CBBCT was more comfortable than mammography in the BMI groups of 18.5～23.9 kg/m$^2$, 24～27.9 kg/m$^2$and ≥28 kg/m$^2$ ($P < 0.05$). There was no significant difference in the < 18.5 kg/m$^2$ group ($P = 0.43$). CBBCT was more comfortable than mammography in both the fatty-breast and dense-breast groups ($P < 0.05$).

*Conclusion:* The comfort of CBBCT was better than mammography.

## 1. Introduction

Breast cancer is the most common malignant tumor and is the main cause of cancer deaths among women, accounting for approximately 626,679 deaths in 2018 worldwide [1]. As an effective method for breast cancer screening, mammography is widely used in clinical practice. Although the success of mammography in screening has been established [2], the limitations of mammography, including tissue superimposition and physical compression of the breast, are documented in the literature [3]. Some patients who are sensitive to pain often felt discomfort during the examination. Hence, it is important to improve the comfort of mammography.

The uncomfortable experience of mammography is related to physiological and situational factors [4–6]. Although compression can reduce the radiation dose, improve image quality, and prevent motion artifacts [7–9], it will increase the discomfort of patients [10–12]. Some research showed that the new paddle had no improvement on the comfort of patients during mammography [13]. Cone beam breast computed tomography (CBBCT) is an isotropic three-dimensional (3D) tomographic imaging technique. It can provide high-quality images

*Abbreviations:* CBBCT, Cone Beam Breast Computed Tomography; NRS-11, 11-point numerical rating scale; BMI, body mass index; FPD, flat panel detector; MLO, mediolateral-oblique; CC, craniocaudal; 3D, three-dimensional

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with a radiation dose range that is comparable to that of diagnostic mammography [14]. Several studies have reported that CBBCT is comparable to mammography in coverage and breast density assessments and has better diagnostic efficiency [15–18]. Patients lie prone on the examination table, with the breast suspended through the opening of the ergonomically designed table without compression during the scan. This study was performed to compare the comfort of patients undergoing CBBCT examination and digital mammography.

## 2. Materials and methods

### 2.1. Patients

This study was performed in Tianjin Medical University Cancer Institute and Hosptial and Sun Yat-sen University Cancer Center from October of 2012 to January of 2014. The study was approved by the ethical committee of each hospital. Informed consent for all subjects was obtained prior to the CBBCT scans. The patients were included in this study based on the following criteria. Inclusion criteria: the patients were over 35 years of age, the interval between CBBCT examinations and mammography was within 1 week, and the patient were in good physical condition to get on and off the scanning table easily. Exclusion criteria: the patients could not be positioned prone on the examination bed due to physical conditions, the patients had contraindications to contrast-enhanced CT, including an anaphylactic reaction to iodine contrast medium or impaired renal function with chronic kidney disease, pregnancy or lactation. Of the 409 qualified patients with ages ranging from 35 to 89 years old (mean ± SD, 48.01 yrs ± 8.085), 217 patients underwent the contrast-enhanced scans, and 192 patients underwent non-contrast scans. There were 163 (39.85%) patients with breast cancer, 97 (23.72%) benign patients, 7 (1.71%) patients with atypical change and 2 (0.49%) patients with borderline phyllodes tumor, as confirmed by pathology. Another 140(34.23%) patients were confirmed benign by a follow-up of more than 6 months.

### 2.2. Equipment

All patients underwent a conventional mammographic examination (Selenia, HOLOGIC, USA and Senographe DS, General Electric Medical Systems, USA) before they received the CBBCT scan in two hospitals. Mammograms were acquired in auto-time mode and automatic compression mode, including views of the mediolateral-oblique (MLO) position and craniocaudal (CC) position. If necessary, patients would undergo local magnification mammography. All images were performed by regular quality controls.

All the CBBCT examinations were performed using the same dedicated breast CT (CBCT 1000, Koning Corpotation, USA) in two hospitals. The CBBCT system consists of a CT gantry that is geometrically optimized for breast imaging, a special high-power mammography X-ray tube (Rad71SP, Varian Medical System, Salt Lake City, UT) with a 0.3-mm focal spot size, an X-ray flat panel detector (FPD) (PaxScan 4030CB, Varian Medical System, Salt Lake City, UT) mounted across from the X-ray tube on the opposite side of the gantry, an ergonomically designed patient table, and a personal computer (PC). The X-ray tube voltage was 49 kVp. The CBBCT system calculated the optimal tube current value, ranging from 50 mA to 160 mA based on breast size and density. The exposure time was 8 ms per projection.

During the scan, the patients were positioned prone on the patient table. The examined breast was set into the opening in the center of the patient table at pendent status without compression. The arm on the side of the examined breast was positioned flat against the patient's body and was extended towards the feet. The arm of the other side was extended in the cephalic direction. The X-ray tube and FPD rotated 360 degrees around the breast and acquired 300 two-dimensional breast projection images in 10 s (Fig. 1). Three-dimensional reconstructed breast images, including three orthogonal planes (sagittal, transverse, and coronal), were obtained by reconstructing the 2D projections.

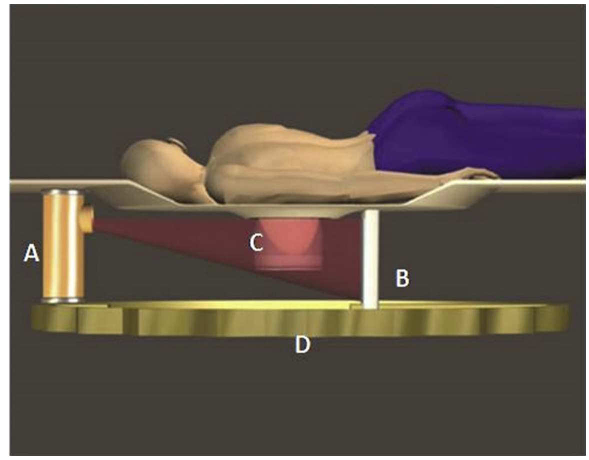


**Fig. 1.** Illustration shows patient lying prone with one breast suspended through tabletop opening into imaging field. A. X-ray tube. B. X-ray flat-panel detector. C. Breast. D. Gantry.

CBBCT has two exam modes, including a non-enhanced mode and a contrast-enhanced mode, which always last approximately 5–10 minutes per exam and 10–15 minutes per exam, respectively. All patients who performed contrast-enhanced CBBCT need to undergo the non-enhanced CBBCT examination first.

### 2.3. Patients' comfort

All patients answered the questionnaire and evaluated the subjective comfort of the CBBCT exam and the diagnostic mammography by using an 11-point numerical rating scale (NRS-11) [19]. Patients scored the degree of comfort based on whether they felt any discomfort during the scan, and chose the most painful parts of the body, such as neck, shoulder, ribs, arm, waist or other parts. The comfort was on a scale from 0 to 10, where 0 represents "no pain" and 10 represents "the worst pain," using whole numbers. The lower the score was, the more comfortable the examination modality was. The patients were divided into different groups based on the CBBCT scan mode, age and the body mass index (BMI) to evaluate the performance on different subgroups and to determine the factors that influence patient comfort. According to the CBBCT scan mode, the patients were divided into the non-contrast scan group and the contrast-enhanced scan group. The patients were divided into three age groups (≤44, 45~54, ≥55). Based on their BMI, the patients were divided into the underweight group (< 18.5 kg/m$^2$), the normal group (18.5~23.9 kg/m$^2$), the overweight group (24~27.9 kg/m$^2$) and the obesity group (≥28 kg/m$^2$).The patients were divided into fatty-breasts (BI-RADS rating A or B) and dense-breasts (BI-RADS rating C or D) using the American College of Radiology Breast Imaging Reporting and Data System categories for breast density [20].

### 2.4. Statistical analysis

All statistical analyses were performed by using SPSS (Version 19.0, SPSS, Chicago, IL). The paired rank sum test was used to compare the degrees of comfort between the CBBCT exam and digital mammography. $P < 0.05$ was considered to be statistically significant.

## 3. Results

### 3.1. Comparison of the comfort between CBBCT and Mammography

All 409 patients answered the questionnaire and evaluated the comfort of the CBBCT examination and the digital mammography by

**Table 1**
Reports of Pain on the Subject Questionnaire during the CBBCT Examination (n = 177).

| Areas of Discomfort | Number of Reports |
|---|---|
| Neck | 109 (26.65%) |
| Shoulder | 34 (8.31%) |
| Ribs | 26 (6.36%) |
| Arm | 6 (1.47%) |
| Waist | 2 (0.49%) |

using NRS-11. Overall, the comfort of CBBCT is better than that of mammography ($P < 0.0001$), but some of the patients felt uncomfortable in other areas during the CBBCT examination. For the patients who reported discomfort, the predominant areas were the neck, shoulder, ribs, arm and waist. The results are presented in Table 1.

In general, the pain score of CBBCT was lower than that of the mammography in 203 patients, was equal with mammography in 140 patients and was higher than mammography in 66 patients. The distribution of the pain score on CBBCT and mammography are shown in Fig. 2. The lower the score was, the more comfortable the examination modality was.

### 3.2. CBBCT exam modes

Of the 409 patients, 192 underwent the non-contrast scan, and 217 underwent the contrast-enhanced scan. CBBCT was demonstrated to be more comfortable than mammography in both CBBCT exam mode groups ($P < 0.0001$). The above results are shown in Table 2. However, the percentage of the patients, who reported the score of CBBCT higher than mammography, was 13.02% for non-contrast scan and 18.89% for contrast-enhanced scan (Table 3). The contrast-enhanced scan of CBBCT was more likely to make patients feel uncomfortable.

### 3.3. Ages

The patient comfort during the CBBCT was shown to be statistically better than mammography for the ≤44 and 45~59 age groups (all P values < 0.0001). There was no significant difference between the CBBCT and mammography for the ≥60 age group ($p = 0.5433$). The above results are shown in Table 2. However, the percentage of patients with a CBBCT score higher than the mammography score was the highest for the ≥60 age group, which indicated that the patients in the ≥60 age group were more likely to feel uncomfortable than the patients in the other groups during CBBCT examination (Table 3).

**Table 2**
Comparison of the Comfort between Cone Beam Breast Computed Tomography and Mammography.

| | | The Score of CBBCT and MG | | |
|---|---|---|---|---|
| | | CBBCT Median (25th,75th) | MG Median (25th, 75th) | P value |
| Modality scan | Non-contrast | 2 (0, 3) | 3 (2, 4) | $p < 0.05$ |
| | Contrast-enhanced | 2 (0, 3) | 2 (1, 3) | $p < 0.05$ |
| Age | ≤44 | 2 (0, 3) | 3 (2, 4) | $p < 0.05$ |
| | 45~59 | 2 (0, 3) | 2 (1, 3) | $p < 0.05$ |
| | ≥60 | 2 (1, 3) | 2 (1.25, 3) | $p = 0.5433$ |
| BMI | < 18.5 | 2.5 (1.75, 3.25) | 2 (1.75,3) | $p = 0.4300$ |
| | 18.5~23.9 | 2 (0, 3) | 3 (2, 4) | $p < 0.05$ |
| | 24~27.9 | 2 (0, 3) | 2 (1, 3.5) | $p < 0.05$ |
| | ≥28 | 1 (0, 2) | 2 (1, 3) | $P = 0.0020$ |
| Breast density | Fatty-breast | 2 (0, 2) | 3 (2, 3.5) | $p < 0.05$ |
| | Dense-breast | 2 (0, 3) | 2 (1.25, 4) | $p < 0.05$ |

The paired rank sum test was used to compare the degree of comfort of the CBBCT exam with that of diagnostic mammography.
25th and 75th represented 25th percentile and 75th percentile of the score of CBBCT and Mammography respectively.

### 3.4. BMIs

The patient comfort during the CBBCT examination was shown to be statistically better than mammography in 18.5~23.9 kg/m$^2$, 24~27.9 kg/m$^2$ and ≥28 kg/m$^2$ groups (all P values < 0.05). There was no significant difference between the CBBCT and mammography in the < 18.5 kg/m$^2$ group ($p = 0.4300$). The above results are in Table 2. The percentage of patients who reported that the score of the CBBCT was higher than mammography for the < 18.5 kg/m$^2$ group was the highest during the CBBCT examination. The results showed that underweight patients were more likely to feel uncomfortable when they underwent CBBCT examination (Table 3).

### 3.5. Breast type

The patient comfort during the CBBCT examination was shown to be statistically better than mammography in fatty-breasted and dense-breasted patients (all P values < 0.05). The above results are in Table 2. The percentage of patients who reported that the score of the CBBCT was higher than mammography for the dense-breast group was the highest during the CBBCT examination. Thus, the dense-breasted patients were more suitable for the CBBCT examination (Table 3).

## 4. Discussion

Based on the results of our study, the patient's comfort during the

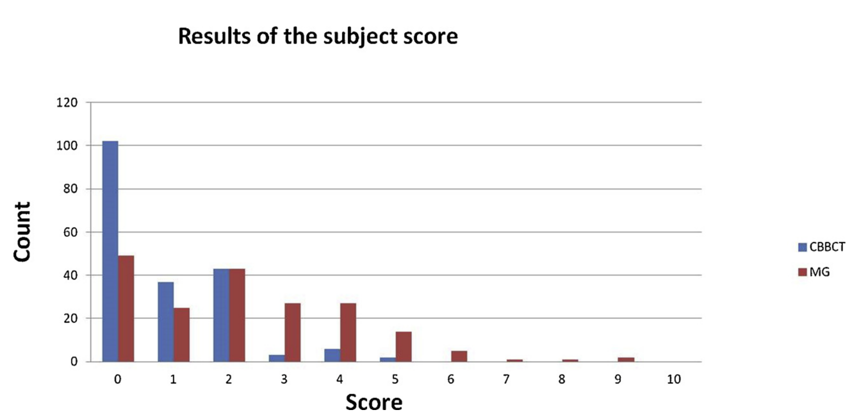


**Fig. 2.** Results of the subject questionnaire. The lower the score, the examination modality is more comfort.

**Table 3**
Distribution of the Number of Patients in different Groups.

| | | The percentage of patients | | |
|---|---|---|---|---|
| | | CBBCT < MG | CBBCT = MG | CBBCT > MG |
| Modality scan | Non-contrast (192) | 113 (58.85%) | 54 (28.13%) | 25 (13.02%) |
| | Contrast-enhanced (217) | 90 (41.48%) | 86 (39.63%) | 41 (18.89%) |
| Age | ≤44 (155) | 88 (56.77%) | 43 (27.74%) | 24 (15.49%) |
| | 45 ~ 59 (214) | 105 (49.07%) | 74 (34.58%) | 35 (16.35%) |
| | ≥60 (40) | 10 (25.00%) | 23 (57.50%) | 7 (17.50%) |
| BMI | < 18.5 (14) | 4 (28.58%) | 5 (35.71%) | 5 (35.71%) |
| | 18.5 ~ 23.9 (210) | 116 (55.24%) | 61 (29.05%) | 33 (15.71%) |
| | 24 ~ 27.9 (133) | 60 (45.11%) | 54 (40.60%) | 19 (14.29%) |
| | ≥28 (52) | 23 (44.23%) | 20 (38.46%) | 9 (17.31%) |
| Breast density | Fatty-breast(117) | 63(53.85%) | 39(33.33%) | 15(12.82%) |
| | Dense-breast(292) | 158(54.11%) | 92(31.51%) | 42(14.38%) |

CBBCT examination was shown to be statistically better than the patients' comfort during mammography. Mammography is widely used in breast screening, which could reduce the mortality of breast cancer for patients over 50 years old [21,22]. However, discomfort during the examination is an obstacle to the application of mammography. The uncomfortable feeling of mammography is related to a variety of factors. In the study by Sullivan et al. [23], the researchers found that increasing force is associated with an increasing likelihood of pain, while the study by Poulos et al. [24] found that breast thickness was also related to discomfort. Of patients, 26% are reluctant to have a mammogram because of the pain, and 96% think the main cause of pain is compression during the examination [25,26]. There are relatively few studies that have shown effective methods to reduce the discomfort of mammography. Hence, it is necessary to utilize another breast imaging method with equal diagnostic efficiency and better comfort for women who are sensitive to pain. As an emerging imaging technique, CBBCT can provide high-quality images and was reported to have higher diagnostic accuracy and sensitivity than mammography. The prone posture during the scan and an opening at the center of the patient table enables the breast to be pendant and uncompressed during the scan, which avoids the compression pain experienced during examination. O'Connell et al. [14] also reported the similar results at the comfort between CBBCT and the mammography by the general feelings of the patients. But in this study, we conducted further quantitative analysis using NRS-11. There was a potentially similar scoring tendency in the comfort scores for CBBCT and mammography in our study. The data distribution showed that there was a small difference between CBBCT and mammography. However, the statistical method showed that the comfort of each group during CBBCT was better than or not lower than that during mammography.

During the CBBCT examination, patients noted discomfort predominately in the neck, shoulder, ribs, arm and wrist at the percentages of 26.65%, 8.31%, 6.36%, 1.47% and 0.49%, respectively. The discomfort of the CBBCT was related to the shape of the patient table and the position of the patients during the examination. Therefore, we should improve upon the comfort for those corresponding areas, which would, in turn, improve the images for the radiologist.

Based on the results of the different modality scans, the comfort of the CBBCT examination was better than that of the mammography in both groups. We found that there were 66 patients who scored a CBBCT higher than that of the mammography. In addition, 41 patients underwent the contrast-enhanced scan, and 25 patients underwent the non-contrast scan. There were two main reasons for this result. On one hand, the discomfort caused by contrast injection during the enhanced scan could influence the overall comfort score. On the other hand, the longer duration of the examination may add to the patients' discomfort for enhanced scan mode. In this study, the average time for the contrast-enhanced scan was 12.6 ± 2.67 min, while the non-contrast scan was 9.67 ± 1.50 min. We thought the duration of the examination could influence the comfort of CBBCT.

There was no significant difference between CBBCT and mammography for the ≥60 age group. The percentage of patients who scored higher comfort for CBBCT than for mammography was highest for the ≥60 age group. This group was more likely to feel uncomfortable during the scan during CBBCT examination. The discomfort could be caused by the following factors. First, the patient's physical limitations and anatomy could affect the comfort of the CBBCT, such as cervical disc herniation, which can increase with age [27]. Second, because the patients lie prone on the patient table and their head faces to the other side, discomfort could increase for the patients. Thus, the age of the patients would influence the comfort of CBBCT.

There was no significant difference between CBBCT and mammography for the BMI $< 18.5\,kg/m^2$ group. In the underweight (BMI $< 18.5\,kg/m^2$) group, the percentage of patients with a higher CBBCT score than the MG score was the highest, which may be related to the following reasons. The underweight patients could feel uncomfortable in the prone position. The shape of the examination table is lower on the head side and higher on the foot side and has a certain slope, which could increase the patient's discomfort. This finding suggested the patients' BMI could influence the comfort of CBBCT during the examinations.

The comfort of CBBCT was higher than that of the mammography in both fatty-breasted and dense-breasted patients. As in prior studies, breast density is a primary predictor of breast discomfort during the mammography examination, especially for dense breasts [28,29]. Thus, the CBBCT could provide for more choices for dense-breasted patients.

Our study first compares the comfort between CBBCT and mammography by using different scan modes, age and BMI, but some limitations of the study should be noted. First, the small size of patients in the group with a BMI $< 18.5\,kg/m^2$ and BMI $\geq 28\,kg/m^2$ was a limitation. We should increase the number of patients in the future study. Second, CBBCT is a new technology that has a different method of patient positioning than that of standard mammography. The experience of the technologists also plays a very important role during examination. Standard operating procedures should be formulated as soon as possible.

## 5. Conclusion

The comfort of CBBCT performed better than the comfort of mammography; thus, CBBCT could be an effective modality for patients who are sensitive to compression. This imaging modality can provide more imaging options for patients with breast disease.

## Declaration of Competing Interest

The authors declare that they have no conflicts of interest concerning this article.

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