*Review*

# Improving Mammographic Image Quality Through Optimized Breast Compression and Patient Comfort

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**Abstract:**
Mammography remains the cornerstone of breast cancer screening and early diagnosis, with image quality and diagnostic accuracy closely dependent on both anatomical and technical factors. Breast compression is a fundamental component of mammographic imaging, as it reduces breast thickness, minimizes tissue overlap, decreases scattered radiation, and enables optimization of radiation dose. Key technical parameters—including compression force and pressure, compressed breast thickness, compression duration, and compression plate characteristics—interact to influence image quality, radiation exposure, and patient experience. Although adequate compression improves contrast and lesion detectability, it may also cause discomfort or pain, potentially affecting patient compliance with screening programs. Patient-related factors, breast density, tissue elasticity, and communication by healthcare professionals further modulate pain perception. The use of low-energy X-ray spectra is essential for achieving high soft-tissue contrast in mammography but requires careful optimization in conjunction with effective breast compression. This review highlights the importance of balancing technical performance and patient comfort to ensure optimal diagnostic outcomes and sustained participation in breast cancer screening.

**Keywords:** Mammography; Imaging; Breast; Compression; Image quality; Pain; Comfort; Discomfort

## 1. Introduction

Breast cancer is one of the most common malignancies affecting women worldwide and early detection is crucial for improving treatment outcomes and reducing mortality. Mammography is the standard imaging technique used for both screening and diagnostic purposes, enabling the identification of breast abnormalities at an early and treatable stage. Despite its widespread use, mammography presents technical challenges and patient - related factors that can influence image quality, diagnostic accuracy, and comfort during examination (Reeves & Kaufman, 2023).

One of the key factors affecting mammographic imaging is breast compression which optimizes image quality, reduces radiation dose, and stabilizes the breast during the procedure. However, compression can also cause discomfort or pain potentially affecting patient compliance with screening programs (Sechopoulos, 2013). This seminar explores the anatomy of the breast, the principles and history of mammography, the technical aspects of breast compression, and strategies to improve patient comfort while maintaining diagnostic effectiveness. Understanding these factors is essential for optimizing mammography procedures and ensuring high-quality, patient-centered breast imaging.

## 2. Design of the Review

A literature review was conducted, selecting articles published between 1983 (Gould, 1983) and 2023 (Strandberg et al., 2023; Ding et al., 2023; Montoro et al., 2023). The review focused on publications describing or examining the anatomical features of the breast, and the role of mammography and breast compression, as well as the technical view of compression and patient comfort. Only studies published in English were included. The reviewed literature comprised a wide range of sources, including peer-reviewed scientific articles, academic textbooks and credible online resources.

## 3. Breast Anatomy

The female breast is located on the anterior thoracic wall, extending from the second or third to sixth rib and to the inframammary fold inferiorly and from sternum medially to the midaxillary line laterally. About two- thirds of the breast lies on the pectoralis major muscle, while the remainder lies over the serratus anterior and abdominal oblique muscles. Breast tissue also extends into the axilla (Gould, 1983; Pandya & Moore, 2011).

The breast is divided into four quadrates, with the upper outer quadrants containing the largest volume of tissue and being the most common site of breast tumors. Breast size and density vary significantly among individuals (Pandya & Moore, 2011).

Most of the breast consists of fatty and glandular tissues. The proportion of these tissues differs among individuals and changes throughout life, including during the menstrual cycle and pregnancy. In general, younger women tend to have a greater amount of glandular tissue, whereas fatty tissue becomes increasingly predominant with advancing age (Ellis & Mahadevan, 2013).

The internal structure of the breast consists of glandular epithelium and surrounding stromal tissue, with glandular tissue forming a relatively small proportion of the total volume. The breast is organized in multiple lobes, which are further divided into lobules containing milk- producing glands. These connect to lactiferous ducts that widen beneath the areola before opening at the nipple. Fatty tissue occupies the spaces between the lobes (Gould, 1983).

## 4. Mammography

Mammography is a radiographic imaging technique used to examine the breast, with the resulting images referred to as mammograms. There are two main types of mammography: screening and diagnostic. Screening mammography is performed on asymptomatic women to detect early- stage cancer when treatment is most effective. Diagnostic mammography is performed on women with breast- related symptoms or to further evaluate abnormalities detected during screening. The primary goal of mammography is to characterize breast pathology through imagining and to establish accurate diagnosis (Gaillard et al., 2008).

## 5. History of mammography

Traditional film mammography has been proven to reduce breast cancer mortality and remains the only widely recommended screening method. However, because its sensitivity is limited, ongoing research focuses on improving early detection. In 1991, a National Cancer Institute workshop identified full- field digital mammography as the most promising technology for enhancing breast cancer detection. Since then, several companies have developed digital mammography systems, many of which received FDA approval and are now used clinically in the world (Lewin, 2008).

## 6. The importance of Breast Compression

Breast compression is one of the key technical elements of mammography imaging, as it significantly affects both image quality and the safety of the examination. During a mammogram, the breast is compressed between a compression plate and a detector, which reduces its thickness and allows for a more even distribution of tissue. Reduced breast thickness leads to less overlap of anatomical structures, which improves the contrast and clarity of mammography images and allows for better detection of pathological changes, such as microcalcifications and small tumor lesions (Poulos et al., 2004).

Another important effect of compression is the reduction of scattered radiation, which negatively affects image quality. Reducing scattered radiation increases the contrast between different tissues, which contributes to better diagnostic accuracy of mammography (Holland et al., 2017). Additionally, compression stabilizes the breast and reduces the possibility of movement during imaging, thereby reducing the risk of blurry or repeat images (Dance et al., 2009).

Breast compression also plays a significant role in optimizing radiation dose. A thinner breast thickness allows for a lower exposure, which reduces the average glandular dose (AGD) without compromising image quality (Sechopoulos, 2013). From the perspective of radiological protection, this is especially important in screening programs, where patients are regularly exposed to ionizing radiation.

## 7. Technical Aspects of Breast Compression

Breast compression in mammography is a complex technical process that influences image quality, radiation dose, and patient experience. Key parameters include compression force and pressure, compressed breast thickness, compression duration, and compression plate properties, whose interactions are essential for optimizing mammographic imaging (Poulos et al., 2004).

### *7.1. Compression Parameters*

The most discussed compression parameter is the compression force, expressed in newtons (N). In clinical practice, applied forces usually range from approximately 80 to 200 N, although they vary according to breast size, shape, elasticity, and the radiographer's subjective assessment (Holland et al., 2017). Higher compression forces reduce breast thickness, improving image quality and lowering radiation dose, but may also increase patient discomfort or pain.

Recently, increased attention has been given to pressure, defined as force per unit area ($N/cm^2$). Unlike absolute force, pressure accounts for the contact area between the breast and the compression plate, as the same force can produce markedly different pressures in small versus large breasts, resulting in unequal patient experience and variable image quality (Holland et al., 2017).

An important technical parameter is the compressed breast thickness (CBT), which directly affects image quality and average glandular dose (AGD). Reduced breast thickness enables lower exposure settings, decreasing radiation dose while also reducing scatter radiation and improving image contrast (Dance et al., 2009).

The compression plate influences how evenly force is distributed across the breast, as its shape, size, and stiffness affect pressure distribution, patient comfort, and compression homogeneity. Modern mammography systems offer plates of various sizes and shapes to accommodate individual anatomy (Sechopoulos, 2013).

*7.2. Variability in Clinical Practice*

One of the important characteristics of breast compression in mammography is its high variability in practice. Studies have shown that there are significant differences in the forces and pressures used between different mammography centers, between individual radiologic technologists, and even between the same technologist for different patients (Poulos et al., 2004; Moshina et al., 2019). This variability is influenced by the experience of the operator, the subjective assessment of the patient's tolerance, the technical characteristics of the device, and organizational protocols. In addition, biological characteristics of the breast, such as density, tissue elasticity, and the patient's age, also play a significant role. Denser and less elastic breasts often require a different approach to compression, as the same force can cause greater pressure and discomfort (Holland et al., 2017).

*7.3. Standardization and future development*

Due to the high variability, the literature often emphasizes the need for greater standardization of compression techniques. Approaches based on target pressure or optimal breast thickness, rather than fixed force, have been proposed to allow for more individualized and equitable treatment of patients (Dance et al., 2014). Technologies for automatic or feedback-controlled compression are also being developed, which could reduce the dependence on the subjective judgment of the operator and improve the reproducibility of the procedure (Sechopoulos, 2013).

## 8. Patient Comfort in Mammography

Mammography plays a key role in the early detection of breast cancer, increasing treatment success and reducing mortality. Therefore, ensuring a positive mammography experience is essential for promoting patient attendance and continued participation in both diagnostic and screening examinations (Ding et al., 2023).

*8.1. Perception of Pain and Discomfort*

During the mammography the breast is compressed onto the detector to be as thin as possible. Numerous studies have demonstrated that breast compression during mammography imposes significant psychological and physical burdens on patients. Psychological assessments have revealed increased cardiac activity and muscle tension in patients undergoing mammographic examinations, reflecting heightened stress responses (Ding et al., 2023).

A substantial proportion of patients report experiencing pain during breast compression, particularly among women who have undergone breast-conserving treatment for breast cancer. Several factors have been identified as contributing to this pain, including anxiety, breast tenderness, density, volume, menstrual status, pain expectations, and the behavior or attitude of medical staff (de Groot et al., 2015).

Pain represents a subjective experience that is primarily affected by psychological, biological, and socio-cultural determinants. Anxiety, fear and pain are considered as the most common psychological responses of mammography. Of these, anxiety is the most prevalent, while fear often acts as a subjective psychological barrier to undergoing the procedure. Catastrophizing is a psychological feature associated with increased pain experience, and in breast cancer it has been studied in relation to treatment adherence, persistent pain, and concerns about recurrence among survivors and their relatives (Montoro et al., 2023).

Most studies investigating pain associated with mammography and related preventive strategies have limited their assessment to pain reported immediately after breast compression. A comprehensive assessment of the temporal evolution of pain, integrated with an analysis of breast mechanical properties, could provide valuable insights for the development of more effective pain-prevention approaches (de Groot et al., 2015).

*8.2. Communication and Approach of Healthcare professionals*

The communication and approach of the healthcare professional should be clear, empathetic, and reassuring, providing patients with thorough information about the procedure and addressing any concerns to reduce anxiety and perceived discomfort. Effective communication about what to expect during the exam has the strongest influence on reducing patient discomfort, followed by using gentler compression and softer paddles. This supports earlier research indicating that the way a technologist interacts with a patient can matter more than the physical discomfort itself. Building a trusting relationship and addressing patients' concerns helps manage fear, discomfort, and feelings of losing control.

While some patients report significant pain, studies show that the actual experience is often less severe than anticipated. Anxiety can also affect whether patients return for future screenings, emphasizing the important role of psychological factors in both pain perception and attitudes toward mammography (Mendat et al., 2017).

*8.3. Strategies to Improve Patient Comfort*

Research on strategies to reduce discomfort during procedures shows a variety of approaches. Many studies explored the use of pain-relieving medications like paracetamol or lidocaine, while others looked at non-drug methods such as music, massage, physical exercises, or multi-sensory relaxing environments. Another approach gaining attention is patient-assisted compression, where individuals control part of the procedure with support from the radiographer, helping to make the experience more comfortable (Ding et al, 2023).

Compression duration also influences pain perception, as longer compression times may increase discomfort even at constant force. Therefore, technically correct and time-efficient examination performance is essential in good mammography practice (Moshina et al., 2019).

Two commonly used strategies to reduce pain during mammography are based on limiting breast compression. The first, known as pain-limited compression, allows patients to stop the procedure when discomfort becomes excessive. The second, known as flattening-limited compression, relies on breast mechanics and automatically terminates compression once further force no longer yields sufficient breast flattening (de Groot et al., 2015).

## 9. Impact of Compression on Mammographic Image Quality

Mammography sensitivity is affected by a variety of factors, with breast density playing a central role, as dense tissue can make tumors harder to detect. Other important elements include how the dense tissue is distributed, the imaging techniques used, compression pressure, x-ray exposure, and the thickness of the compressed breast. While some of these factors have been studied individually, there is limited population-based research examining how x-ray exposure, compression pressure, and breast thickness together influence screening sensitivity (Strandberg et al., 2023).

Breast density also changes naturally with age, typically decreasing around menopause, which makes it essential to account for age-related differences when evaluating screening outcomes. Furthermore, density measurements can vary depending on breast positioning and imaging settings, affecting both automated software assessments and radiologist evaluations. For this reason, tracking density and imaging parameters over time is crucial for a more accurate understanding of what influences mammography performance (Strandberg et al., 2023).

## 10. Discussion

Mammography is essential for early breast cancer detection, but breast compression often causes pain and discomfort that can reduce patient adherence. Patient-centered strategies and careful assessment of pain in relation to mechanical parameters can improve comfort without compromising image quality (Ding et al., 2023).

Breast compression is a key factor in mammography, influencing image quality, radiation dose, and patient experience. Parameters such as force, pressure, compressed breast thickness, duration, and plate properties are closely linked and determine diagnostic effectiveness (Poulos et al., 2004; Holland et al., 2017; Dance et al., 2009). While higher compression improves contrast, reduces scatter, and lowers dose, it may increase patient discomfort, affecting screening acceptance (Moshina et al., 2019).

Variability in practice underscores the need for standardization, individualized approaches, and pressure-based parameters (Holland et al., 2017). Combining technical knowledge, procedure standardization, and patient comfort is essential to balance diagnostic quality, safety, and patient experience, enhancing screening effectiveness.

## 11. Conclusion

The female breast is a complex structure of fatty and glandular tissue arranged in lobes and quadrants, with size and density varying among individuals and across life stages. The upper outer quadrant contains the largest tissue volume and is the most common site of breast cancer. Mammography is a radiographic imaging technique used both for screening asymptomatic women and diagnosing abnormalities, with the primary goal of accurately detecting and characterizing breast disease. Breast compression during mammography enhances image quality, reduces radiation exposure, and stabilizes the breast, but because it can cause discomfort, balancing diagnostic effectiveness with patient comfort is essential.

**Conflicts of Interest:** The authors declare no conflict of interest.

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