The effect of magnification technique on the optical density and size of object on mammography

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Abstract. To visualize the existence of micro-calcifications in mammography there are a number of ways carried out including by the magnification technique. This study evaluates the effect of magnification technique on optical density (OD) and size of the objects of the image produced on mammography. The objects used were three circular coins. Source to image distance (SID) was 65 cm, with a focal spot size of 0.1 cm, a combination of targets/filters was Mo/Mo with a filter’s thickness of 30 µm. The tube loading was 100 mAs, the tube voltage was 27 kVp, and the magnification was in the range of 1.00–2.00 times with an increase of 0.25. Measurement of OD and size of the objects was using an ImageJ software. The results of this study revealed that the OD value decreases proportional to the magnification. The OD values calculated on the 2x magnification were 13.74, 14.26, and 13.44% lower than 1.0 magnification (without magnification), while the resulting image will be oval in proportion to the position of the coin from the chest wall and the magnification. An implementation of the magnification method in the mammography must be carried out with caution. In addition to a benefit to larger appearance of micro-calcification, it also causes a decrease in OD and distortion of objects in the image.

1. Introduction
Screening for breast cancer by mammography aims to detect cancer at an early stage, so that treatments can be performed earlier [1,2]. Magnification technique in mammography is performed on women presenting with breast complaints or abnormalities [3]. Magnification technique in mammography is to increase the visibility of relatively small structures and is usually performed as a complement of standard mammography technique [4-7]. An advantage of the magnification technique is to clearly show the small organ structures. This is in accordance with one of the principles of macro radiography, i.e. small details become larger [8] An implementation of the magnification technique should carefully consider several aspects, i.e. the reduction in image quality and the different impact on the patient's dose [2]. Due to these considerations, therefore, the magnification technique is not recommended as the main procedure. Hence, the magnification technique is performed if an additional information is needed after implementation of standard mammographic examination [3,9].

Several studies have been conducted and reported an advantage of the magnification technique to clarify micro-calcification [9], however it also has disadvantages such as reduced image quality and increased radiation dose to patients [3,10]. A relationship between magnification and image quality is still in need to be deeply explored. Therefore, this research aimed to determine the relationship between changes in object distance (magnification) and image quality in terms of optical density and the size (distortion) of the resulting image. It is hoped that it can be useful as a reference for the relationship...
between magnification and image quality on mammography examination so that an optimization can be properly carried out.

2. Methods
The current study evaluated a Mammography X-Ray unit (Siemens, Mammomat 1000/3000 Nova). A multipurpose detector (MPD) with Ocean software (Piranha, RTI Electronics, Sweden), mammographic accreditation phantom, ruler, styrofoam, metal coins, ImageJ software, and micro-meter screws were used.

Before testing the image quality, an appropriate exposure factor was needed to be found, because the automatic exposure control (AEC) was implemented in this mammographic device. For this purpose, the mammographic accreditation phantom was scanned with a target/filter combination of Mo/Mo with a filter’s thickness of 30 µm. Measurement of tube loading (mAs) and tube voltage (kVp) was carried out first as the standard reference for the exposure factor used in standard breasts with a 50% adipose percentage and a 50% glandular tissue. An arrangement of appropriate exposure determination is shown in figure 1.

![Figure 1. An arrangement for determining the appropriate exposure factor using the mammographic accreditation phantom](image)

The next step after obtaining the appropriate exposure factor will be an observation of the decreasing image quality in terms of optical density and distortion of the image. For this purpose, three coins were placed at various locations were irradiated. One coin was located close to the chest wall (coin #1), one coin was in the middle of the irradiation field (coin #2), and one coin was far from the chest wall (coin #3). The coins positions can be seen in Figure 2.
Figure 2. Three coins position for evaluating their optical densities and distortion of the image.

The distance from the source to the image (SID) on the mammography machine was 65 cm. The placement of the object's height will be adjusted to the variation of the magnification, namely 1x, 1.25x, 1.5x, 1.75x, and 2.0x. The distance from the source to the object (SOD) and the distance from the object to the image (OID) were calculated using equation (1).

\[ M = \frac{SOD + OID}{SOD} = \frac{SID}{SOD} \]  

(1)

M indicated the magnification. Styrofoam was used as a buffer for coin objects positioning at various heights. After the coins positions were correct, the next step was to manually expose it using the expansion factor obtained from the AEC mode, namely tube voltage (kVp) and tube loading (mAs). Subsequently, the film was processed to produce an image and an analysis of the results of the image was carried out using the ImageJ software. The research setting using coins was shown in figure 3.

Figure 3. Research setting using coins for evaluating optical density and distortion due to magnification technique
The optical density was measured from resulted images using an ImageJ image processing software. The coins were in a circular shape. Diameters of coins were measured horizontally (left and right direction) and vertically (front and back). Afterwards, the diameters were measured from the resulted images using an ImageJ. The difference between these two measurements showed the impact of magnification on object size and distortion (if any). The general description of the research is as shown in figure 4.

**Figure 4.** Flow charts for determinations of the exposure factor (a) optical density and image size (b)

### 3. Results

**3.1. Measurement of the exposure factor**
Measurements of tube loading (mAs) and tube voltage (kVp) were carried out first as a standard reference for the exposure factor used in standard breasts with a percentage of 50% adipose and 50% glandular tissue. The measured tube loading was 103 mAs and tube voltage was 27 kVp, but in the manual setting of the tube loading value did not have a value of 103 mAs so that in this study the value of 100 mAs was used as an approximate value.
Magnification was set by changing the distance either the distance from the source to the image (SID), the distance from the source to the object (SOD), or the distance from the object to the image (OID). Magnification could be done in two ways, the first was by changing the SID distance with a fixed SOD distance. The second way was to change the SOD with a fixed SID [11]. In this research, the second method was chosen. The magnification was calculated with equation (1). The resulting SOD and OID values were shown in table 1.

Table 1. SOD and OID values for magnification from 1.00 to 2.00.

| No. | Magnification | SOD (cm) | OID (cm) |
|-----|---------------|----------|----------|
| 1.  | 1.00          | 65       | 0        |
| 2.  | 1.25          | 52       | 13       |
| 3.  | 1.50          | 43       | 22       |
| 4.  | 1.75          | 37       | 28       |
| 5.  | 2.00          | 32.5     | 32.5     |

3.2. Effect of magnification on optical density

Measurements of the images of three coins were found with various magnification (Figure 5). The Source to image distance (SID) was 65 cm. A coin #1 was located closest to the chest wall, a coin #2 was located in the middle one, while a coin #3 was located farthest from the chest wall. Figure 5 showed images for each coin object in each magnification variation. The coin object on the right was closest to the chest wall (coin #3).

Figure 5. Images for the magnification variation, (a) 1.00x, (b) 1.25x, (c) 1.50x, (d) 1.75x, and (e) 2.00x

The optical density (OD) values for various magnification levels are obtained from images of three coins located at different positions. The OD values are measured using ImageJ software and their results can be seen in Table 2. It clearly showed that the OD decreases in proportion to the increase in the
magnification value used. The OD values calculated for the 2x magnification variation were 13.74, 14.26, and 13.44% lower than the 1.0x magnification (without magnification) for coins #1-3, respectively.

Table 2. Optical density and deviation values for without magnification (M = 1) and with various magnifications.

| Magnification (M) | OD coin #1 | Deviation against M = 1 (%) | OD coin #2 | Deviation against M = 1 (%) | OD coin #3 | Deviation against M = 1 (%) |
|-------------------|------------|-------------------------------|------------|-------------------------------|------------|-------------------------------|
| 1.00              | 0.655      | 0.00                          | 0.659      | 0.00                          | 0.640      | 0.00                          |
| 1.25              | 0.605      | 7.63                          | 0.614      | 6.83                          | 0.593      | 7.34                          |
| 1.50              | 0.598      | 8.70                          | 0.598      | 9.26                          | 0.592      | 7.50                          |
| 1.75              | 0.582      | 11.15                         | 0.582      | 13.23                         | 0.570      | 10.94                         |
| 2.00              | 0.565      | 13.74                         | 0.565      | 14.26                         | 0.554      | 13.44                         |

3.3. Effect of magnification on size of objects in the image
Table 3 presented the results of image measurements for each magnification variation using ImageJ software. The size of the measurement results through the ImageJ software will then be compared with the actual size generated by the calculation. The differences in coin and image sizes were calculated and tabulated in Table 4. It showed that deviation in image size for various magnification in the x-direction. The deviation increased with the increase of magnification for y-direction. This led to distortion of the images. The values obtained on the y-direction (front and back) from the closest position to the chest wall to the farthest position were 0.54, 0.57, and 0.67 cm, respectively. For the x-direction (left and right direction) from the closest position to the chest wall to the farthest position, the values of differences were 0.11, 0.13, and 0.22 cm, respectively.

Table 3. Results of image measurements for each magnification using manual measurement and using an ImageJ software.

| Coin number | Magnification (M) | Diameter of object measured manually (cm) | Image diameter measured using ImageJ (cm) |
|-------------|-------------------|------------------------------------------|-----------------------------------------|
|             |                   |                                          | x-direction                              | y-direction |
| #1          | 1.00              | 2.01                                      | 2.02                                    | 2.22        |
|             | 1.25              | 2.51                                      | 2.55                                    | 2.82        |
|             | 1.50              | 3.02                                      | 3.09                                    | 3.42        |
|             | 1.75              | 3.52                                      | 3.65                                    | 4.03        |
|             | 2.00              | 4.02                                      | 4.13                                    | 4.56        |
| # 2         | 1.00              | 2.01                                      | 2.02                                    | 2.23        |
|             | 1.25              | 2.51                                      | 2.55                                    | 2.83        |
|             | 1.50              | 3.02                                      | 3.11                                    | 3.43        |
| Coin number | Magnification (M) | Difference in size (diameter) of the coins (cm) |
|-------------|------------------|-----------------------------------------------|
|             |                  | x-direction | y-direction                      |
| #1          | 1.00             | 0.01        | 0.21                             |
|             | 1.25             | 0.03        | 0.31                             |
|             | 1.50             | 0.08        | 0.41                             |
|             | 1.75             | 0.13        | 0.51                             |
|             | 2.00             | 0.11        | 0.54                             |
| #2          | 1.00             | 0.01        | 0.22                             |
|             | 1.25             | 0.04        | 0.32                             |
|             | 1.50             | 0.09        | 0.41                             |
|             | 1.75             | 0.14        | 0.56                             |
|             | 2.00             | 0.13        | 0.57                             |
| #3          | 1.00             | 0.04        | 0.26                             |
|             | 1.25             | 0.06        | 0.37                             |
|             | 1.50             | 0.14        | 0.50                             |
|             | 1.75             | 0.18        | 0.61                             |
|             | 2.00             | 0.22        | 0.67                             |

**Table 4.** The difference between the size of the coin (measured manually) and measured from image using an ImageJ software.

### 4. Discussions

Although magnification technique in mammographic examination has an advantage to clearly show the small structures (micro-calcification), however its implementation should be performed carefully. The current study finds that magnification leads to decrease the optical density and increase the image distortion. Other studies reported that the magnification technique also affected the radiation dose [3,10], however this is not investigated by the current study.
Table 2 indicates the impact of the magnification to the optical density value. It clearly seems that the optical density decreases with increasing magnification. This is because the decreasing intensity that hits the object due to shorter distance from the source to the object (SOD).

These results also indicate that the optical density for coin #2 is higher or equal to coin #1. This happens because in the mammography, the X-rays emitted are in the form of a right triangle, which is different from the radiographic in general with the shape of an isosceles triangle [12]. So, the beam travel farthest at coin #3. In addition, heel artifact also affects the intensity, i.e. smallest intensity is at coin #3. Therefore, coins #1 and #2 had no very different optical densities, and coin #3 has smallest optical density. The illustration of the location of the coins and the center of the X-ray beam on the field of irradiation can be seen in figure 6.

![Figure 6](image6.png)

**Figure 6.** The direction of the X-ray (a), the position of the coins on the irradiation field (b).

The magnification changes the shape the resulting image. In this study, circular coin objects are investigated, so the resulting image will be oval in a y-direction, proportional to the farther position from the chest wall and the magnification. The results show that the entire image size increases with the increase in the magnification, this is due to the greater distance from the object to the image receptor (OID).

Figure 7 shows the beam intensity and travelling distance of the beam resulting difference in y-direction measurements. The size in y-direction will be greater when compared to x-direction measurements. This beam will make the resulting image of the objects change their shapes, for example, in this study, circular coin objects will be oval in a y-direction proportional to the farther position the coin from the chest wall and the magnification. This is because a farther distance from the chest wall, the beam travels longer distance to the image (SID) and object will be greater.

![Figure 7](image7.png)

**Figure 7.** X-ray beam in mammography unit. (a) Chest wall is at edge of the beam, and the beam travel shortest distance to the image (SID) (b) Center of the beam is at center of the mammæ. Farther distance from the chest wall, the intensity of the beam decreases and beam travels longer distance to the image (SID).
5. Conclusion
Magnification variations have an effect on optical density (OD), size and distortion of the objects. The OD values decrease with the increase of the magnification. The OD values calculated for the 2x magnification from the position closest to the chest wall (coin #1) were 13.74, 14.26, and 13.44% lower than the 1.0x magnification. Magnification variations have an effect on the size and shape of the resulting image. The change in shape of the object from a circle to an oval at y-direction is proportional to the position of the coin from the chest wall and the magnification used. The difference in size to the y-direction with a 2x magnification of 0.54, 0.57, and 0.67 cm, while the differences in size to the x-direction with a 2x magnification are 0.11, 0.13, and 0.22 cm.

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