1 Why Mammography?

Why Mammography? The Clinical Reasons, by Liz Bowey

When first considering the topic of "Why mammography?", any instinctive reaction should be "Why not?" Mammography can be used as a screening tool in asymptomatic women, or as a diagnostic tool to investigate lumps or changes to the breast. In both cases, it is a really important part of caring for women's health and well-being. Mammography is currently the best way to discover early breast cancers. It can detect breast cancer before it shows physical symptoms. Mammograms have also been proven to reduce the risk of dying from breast cancer which affects up to one in eight women in their lifetime. Early detection of cancers and precancerous lesions has increased with continual improvements in mammography. Early detection/early diagnosis is still the best way of ensuring a good outcome, so why would we not make use of mammography?

Most women in developed countries have access to free screening mammography. Those who have symptoms that

Digital Mammography: Physics and Instrumentation, Second Edition.
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need close follow-up, or are following up on a suspicious area, will need diagnostic mammography which is often accompanied by breast ultrasound and other breast image modalities as needed to assist in making the diagnosis. The mammogram, whether screening or diagnostic, is a low-dose X-ray examination, and both use the same type of equipment and require well-trained staff.

Good mammography is a combination of many things. Digital mammographic image examples are shown in Figure 1.1. Having access to state-of-the-art equipment is paramount. The importance of this will be covered in the rest of this book. Well-trained mammographers and radiologists are the other essential requirements to produce good mammography. A good

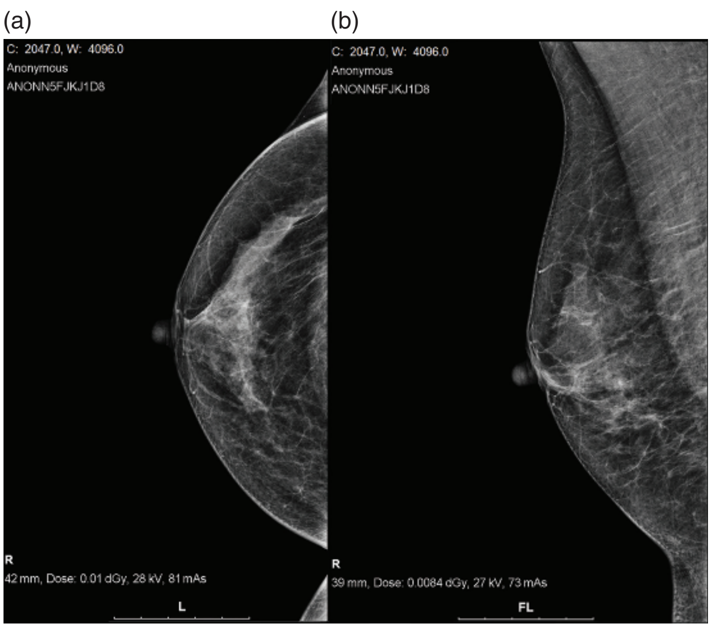

Figure 1.1 An example of a digital mammographic examination of the right breast. (a) A cranio-caudal view *and* (b) a mediolateral oblique view. *Source:* With permission of BreastScreen ACT, Canberra, Australia.

mammographer/mammography technologist will put the client at ease. This is essential as it is easier to position a breast and get really good coverage if the client is relaxed. Getting a few more millimeters of breast tissue into the field of view can mean seeing a cancer that may have been missed. It is a real skill to achieve the best positioning possible for each client. Breast shape and size, body habitus, and client maneuverability are just a few of the issues to deal with. The procedure is also much less uncomfortable for the relaxed client than a tense one!

Why Digital Mammography? An Overview of the Technical Reasons, by Rob Davidson

Currently, planar X-ray imaging, including mammography and general X-ray imaging, uses digital radiography (DR) recording methods. DR imaging requires the anatomy of interest to have differing amounts of X-ray attenuation, also known as subject contrast, so the X-ray exit intensities from those anatomical regions differ by at least 5%. In general X-ray DR imaging, anatomical regions, for example, of the chest and bones, the attenuation difference in that anatomical region is significantly greater than 5%. If the attenuation differences are less than 5%, the detectors will not be able to detect differences in the X-ray beam's exit intensities and there will be no differences in gray levels and image contrast in the displayed image.

One of the main advantages of computed tomography, arguably the main advantage, is CT's low contrast resolution of around 0.25%. In other words, there needs to be an anatomical subject contrast of greater than 0.25%. The advantage of this is seen in CT imaging of the brain and abdomen, where general planar X-ray imaging cannot visualize gray matter/white matter differences and has difficulty in visualizing different abdominal organs.

The breast tissue is composed of fibroglandular, adipose, blood vessel, and ductal tissues. These tissues and breast cancers have very similar X-ray attenuation characteristics. Figure 1.2 shows a plot of linear attenuation of fibroglandular, adipose, and cancer tissues. Linear attenuation coefficients of all matter decrease in differences as X-ray photon energies are increased. General planar X-ray imaging typically has its lowest peak voltage, kVp, setting at 40 kVp; however, higher kVp settings are generally used. Mammography X-ray imaging units have lower kVp settings and hence lower X-ray photon energies can predominate in the X-ray beam. Using lower X-ray photon energies, breast tissues have greater X-ray attenuation difference and breast cancers can be visualized from healthy breast tissues.

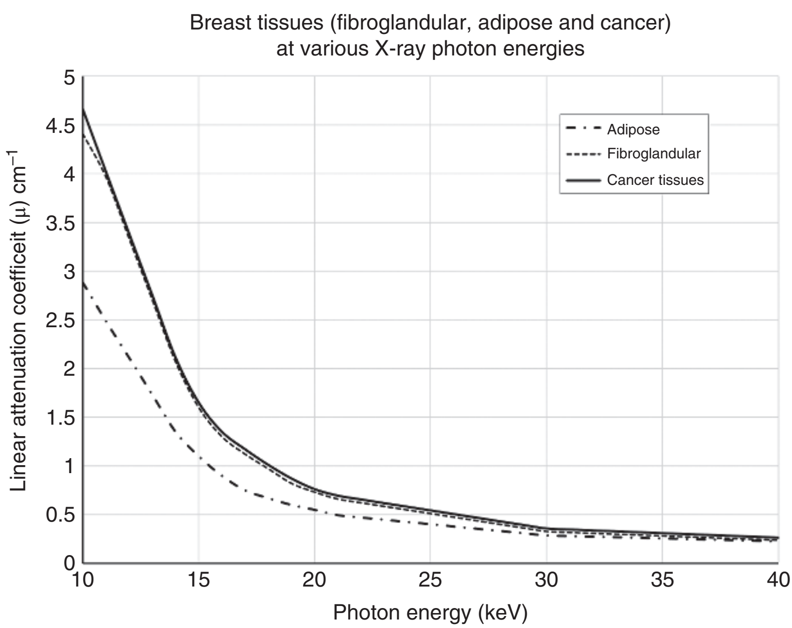

Figure 1.2 A plot of linear attenuation coefficients of breast fibroglandular, adipose, and cancer tissues at various photon energies (keV).
Source: Adapted from Hubbell and Seltzer (2004), and Soares, Gobo et al. (2020).

Mammography X-ray tubes' target and filtration material are also designed to optimize the X-ray photon spectrum and energies. General X-ray tubes typically have tungsten targets, primarily to maximize X-ray photon production, and aluminum filters, primarily to reduce the number of low-energy X-ray photons reaching the patient that would increase the radiation dose to the patient. Such general X-ray tubes are not designed nor optimized for imaging anatomy with a low inherent subject contrast.

X-ray image contrast is partially dependent on the thickness of the object being imaged. Image contrast is reduced and image quality is degraded when X-ray photons are scattered by the object and reach the image detector. The greater the object thickness, the greater the amount of scattered radiation. Compression is used to reduce breast thickness and improve image contrast and hence able to visualize greater differences between cancers and normal breast tissue. Compression in general X-ray imaging is rarely used clinically.

An X-ray image's spatial resolution, the ability to record and display detail in the image is primarily dependent on both the spatial details of the detector and the size of the focal spot where the X-ray photons are produced. The smaller the detector's pixel size and the smaller the focal spot, the greater the spatial resolution of the system. Breast imaging needs to be able to detect very small objects such as mammary microcalcifications (MCs). The presence of MCs can indicate premalignant and malignant breast lesions. General X-ray unit detectors typically have pixel sizes between 120 and 160 µm, whereas mammography unit pixel sizes are typically between 70 and 100 µm. The X-ray tube focal spot is much smaller in mammography units compared to general X-ray units. Typically, in a mammography unit, the focal spot sizes are: the small focal spot is around 0.10–0.15 mm, and the large focal spot is around 0.3 mm. Common general X-ray tube focal spot sizes are: the small focal spot is 0.6 mm, and the large focal spot is around 1.2 mm.

With small focal spot sizes, the X-ray tube filament current is much less than the current used in general X-ray tubes. Typical mammography filament currents are: 10–50 milliamps (mA) used for the small focal spot and 100–200 mA for the large focal spot. Large focal spot currents in general imaging can be 1,000–2,000 mA and even higher for angiography units. The time of the X-ray exposure is dependent on the mA being used and on the distance of the source of X-rays, the source-to-image distance (SID). To keep exposure times in mammography shorter, the SID is reduced compared to typical SIDs of 100 cm in general X-ray imaging.

An X-ray beam diverges as it travels from the focal point. The central ray of an X-ray beam is usually aligned so it will be at a right angle to the center of the detector/image plate. If this approach was used in mammography, the breast tissue near the chest wall furthest from the image plate would not be in the X-ray beam and as such, not imaged, potentially missing pathology. Mammography X-ray units' designs are to angle and align the X-ray tube so that the X-ray beam is at a right angle to the edge of the image plate that is closest to the patient's chest wall. This approach in mammography units allows the beam to skim the chest wall and include the maximum amount of breast tissue in the image.

Other X-ray mammography technologies that require digital techniques have been developed. These are digital breast tomosynthesis (DBT) and contrast-enhanced digital mammography (CEDM).

These mammography characteristics discussed earlier have been developed over many years. Prior to 1969, general X-ray units with tungsten targets and X-ray film were used for breast imaging. Mammography unit development has made many changes since the 1960s and the main ones are given in Table 1.1.

The following chapters will discuss in more detail the physics and instrumentation requirements in digital mammography to create images that assist in the diagnosis of breast cancer and other breast diseases.

Table 1.1 X-ray Mammography Unit Development Timetable.

Year	Development
1969	Dedicated mammography unit with molybdenum target and compression
1971	Xerography mammography unit
1972	Dedicated mammography film-screen systems
1977	Micro-focal spot sizes for magnification mammography
1978	Mammography grids
2000	Digital mammography unit
2011	Digital breast tomosynthesis (DBT) and contrast-enhanced digital mammography (CEDM)

Bibliography

Diffey, J. L. (2015). "A comparison of digital mammography detectors and emerging technology." *Radiography* 21(4): 315–323.

Fredenberg, E., Willsher, P., Moa, E., Dance, D. R., Young, K. C. and Wallis, M. G. (2018). "Measurement of breast-tissue x-ray attenuation by spectral imaging: fresh and fixed normal and malignant tissue." *Physics in Medicine & Biology* 63(23): 235003.

Haus, A. G. (2002). "Historical technical developments in mammography." *Technology in Cancer Research & Treatment* 1(2): 119–126.

Hubbell, J. and Seltzer, S. (2004). X-ray mass attenuation coefficients, NIST Standard Reference Database 126. Technology, N. I. o. S. a.

Kalaf, J. M. (2014). "Mammography: a history of success and scientific enthusiasm." *Radiologia Brasileira* 47(4): Vii-viii.

Logullo, A. F., Prigenzi, K. C. K., Nimir, C., Franco, A. F. V. and Campos, M. (2022). "Breast microcalcifications: past, present and future (Review)." *Molecular and Clinical Oncology* 16(4): 81.

Nicosia, L., Gnocchi, G., Gorini, I., Venturini, M., Fontana, F., Pesapane, F., Abiuso, I., Bozzini, A. C., Pizzamiglio, M., Latronico, A., Abbate, F., Meneghetti, L., Battaglia, O., Pellegrino, G. and Cassano, E. (2023). "History of mammography: analysis of breast imaging diagnostic achievements over the last century." *Healthcare* 11(11): 1596.

Soares, L. D. H., Gobo, M. S. S. and Poletti, M. E. (2020). "Measurement of the linear attenuation coefficient of breast tissues using polienergetic x-ray for energies from 12 to 50 keV and a silicon dispersive detector." *Radiation Physics and Chemistry* 167: 108226.

Tomal, A., Mazarro, I., Kakuno, E. M. and Poletti, M. E. (2010). "Experimental determination of linear attenuation coefficient of normal, benign and malignant breast tissues." *Radiation Measurements* 45(9): 1055–1059.