Differences in grid and air gap techniques

Environment, Air

Introduction

In this chapter, a literature review was carried out so that adequate information about the differences in grid and air-gap technique could be gathered with emphasis on why these techniques are important in plain radiography of the lateral hip. These two techniques will be analysed to explain better the acquisition of the image. Both techniques will be compared and their advantages and disadvantages discussed. This was done by means of radiography books and journals. Where, possible primary sources of information were chosen. However, original studies could not always be obtained and secondary sources had to be considered. The use of the internet was also important as it served as a source for and access to relevant articles. Related literature was mainly sourced using the online data bases of EBSCO®, CINHAL® and Pubmed® as well as the Institute of Health Care's library and facilities.

Image quality

Image quality refers to the ability to view the anatomical structure under study with precision and which makes it possible to identify and spot any abnormalities (Bushong, 2008). The quality of the image depends on several physical and physiological factors and this makes it hard to measure. Image quality;

" Is defined in radiological terminology as the relationship between the structures of a test sample to be irradiated with x-rays and the parameters of its visualisation" (Hertrich, 2005, pg. 244)

According to Bushong (2008), the most important factors that improve or degrade image quality are contrast resolution, spatial resolution, noise and artefacts. Image quality cannot be measured in a precise way since the quality of radiographs is hard to define (Bushong, 2008).

In digital radiography (DR) the image quality depends on a number of characteristics that can change the viewing experience. One of these factors is frequency, which is a measure of the total amount of contrast within the image. This characteristic depends on the raw data (x-ray energy) that the imaging detector absorbs. The frequency of the image is represented by different grey scale levels that show the density of a particular part of the anatomical structure. This is how contrast is affected. A high contrast image has high frequency due to the amount of x-ray photons absorbed (Carlton & Adler, 2006).

Image quality is also subjective and depends on the viewer (Sherer et al., 2006). Different people may need to alter the quality of the image by increasing or reducing the contrast or by changing the sharpness of the image depending on their individual visual abilities (Dendy & Heaton, 2003). Dendy and Heaton (2003) argue that image quality also depends on the display system and the way the image is produced. The authors further argue that room lighting also affects image quality and might also diminish image quality.

Image contrast

Image contrast refers to the difference in densities between adjacent anatomical structures. The amount of contrast produced on an image depends on the structural characteristic of the anatomical part of the body as well as the characteristics of the x-ray beam when it penetrates the patient’s body. Contrast depends on the attenuations within the patient’s body due to different densities in various parts of the body. The higher the difference in densities, the higher is the contrast (Sherer et al., 2006). However, small changes in densities of structures would not be detected on a high contrast image since high contrast does not have a great enough exposure latitude to give several shades of grey in the image (Bushong, 2008). This means that having high contrast in an image does not necessarily mean that it is optimal for every radiographic examination. Having low contrast means that better contrast resolution is produced and this gives the viewer the ability to differentiate between anatomical structures that have similar densities. This is why contrast is a very crucial factor in image quality (Oakley, 2003). Scattered radiation affects image contrast and the characteristics of the receptor and display system. The anatomical detail and contrast of small anatomical structures may also be reduced due to image blurring (Carlton & Adler, 2006).

Noise

Noise affects the image’s contrast resolution and the detail seen in the image. Like audio noise and video noise, radiographic noise is caused by weak signals in areas of the image (Oakley, 2003). The lower the noise the better the contrast resolution and so image quality is better. According to Bushong (2008), there are four main components that affect radiographic noise. These are graininess, structure mottle, quantum mottle and scatter radiation. Graininess and structure mottle cannot be controlled by the radiographer since they are dependent on the image receptor. However, the radiographer can use several techniques and exposure factors to improve image quality and reduce the noise as much as possible depending on the subject under examination. Penetration energy of the x-ray photons (kV) can be increased in subjects that are obese and that are having thick areas of their bodies irradiated. Quantum mottle is also a very important characteristic in defining noise. Bushong (2008) explains that quantum mottle depends on the amounts of x-rays that are exposed and absorbed by the image detector. When few x-rays react with the receptor the resultant image will appear mottled. However, when more x-rays are absorbed by the detector, the image will appear smooth. Noise can be calculated by measuring the signal-to noise ratio of the image (Bushong, 2008). If not enough x-ray photons reach the detector, the image is said to be under-exposed, resulting in a low signal-to-noise ratio. However, a high signal-to-noise ratio is achieved if the right radiographic technique is used with the right exposure factors (Bushong, 2008).

Spatial Resolution

Spatial resolution is a term used in imaging that refers to the resolution of a radiograph. Having a high resolution means that more detail can be seen and detected on the image. Spatial resolution is a very important performance indicator in radiography. Quality control phantoms are used to check the spatial resolution and contrast of an imaging system. Spatial resolution relies on spatial frequency and this quantity could be calculated by seeing the number of line pairs per millimetre (Lp/mm). These line pairs are dark and white lines that are used to assess the resolution of an image.

Detail is very important in radiography since outlines of tissues, organs and specific pathologies need to be sharp and detailed. High spatial resolution is also important when assessing for subtle fractures like scaphoid fractures which could easily be missed if the radiograph is not sharp enough (Bushong, 2008).

Scatter Radiation

When x-ray irradiation encounters matter, some photons pass unimpeded reaching the image receptor whereas other photons are completely absorbed since the energy of the primary x-ray beam is deposited within the atoms comprising the tissue. This absorption interaction of x-ray photons with matter is known as the ‘ photoelectric effect’ (Fauber, et al, 2009). This photoelectric effect is dependent on the matter and its effect decreases rapidly with increasing photon energy (Dendy & Heaton 2003). Scatter radiation is made up of photons that are not absorbed but instead lose their energy during interactions with the atoms making up the tissue (Fauber, et al, 2009). This scattering effect is known as the ‘ Compton effect’ (Carlton and Adler, 2006). This happens when the incoming photon interacts with matter and loses energy. This will make the photon change direction and it may leave the anatomic part to interact with the image receptor (Fauber et al, 2009). Scattered low- photon energy reduces the contrast on the final radiograph and is also highly hazardous for patients and staff due to its changed direction and low energy from the primary beam (Dendy & Heaton, 2003).

Scatter Reduction

As explained above, scatter radiation is produced during a Compton interaction in which a primary photon interacts with an atom of the patient’s body and loses its speed and direction. Scatter is produced mainly in the patient due to the variable attenuation and densities of the different organs in the body and this could be controlled by using anti-scatter techniques and the right exposure factors. Consequently the radiographer should use the adequate technique and exposure factors to reduce the radiation produced within the patient’s body. Carlton and Adler (2006) argue that when the energy of the primary beam is increased there is a higher chance for the photons to undergo the Compton interaction. This means that the higher the energy given to the photons (kV) the more likely it is that there is Compton interaction with the body’s atoms, therefore creating more scatter radiation and a decline in radiographic contrast (Bushong, 2008; Carlton & Adler, 2006). However, Shah, Hassan & Newman (1996) think otherwise. In their study they stressed the effectiveness of anti-scatter techniques on image contrast and concluded that the influence of kV on scatter production is small. The authors further stated that the improvement in contrast that occurs when the kV is lowered is usually due to an increased subject contrast since less scatter reaches the film. Carlton and Adler (2006) also gave importance to the size of the area of body being irradiated. They suggested that by decreasing the area of irradiation as well as applying compression, scatter radiation reaching the detector could be significantly reduced. Using this technique Shah, Hassan and Newman (1996) noted a decrease in the dose area product (DAP) when decreasing the area of irradiation, therefore lowering the risk of increasing patient dose.

Anti-scatter techniques

Anti-scatter techniques are radiographic techniques that make use of devices or applications such as grids and air gaps so that scatter radiation is absorbed or deviated from reaching the image detector. These anti-scatter techniques help in reducing patient dose as well as improving the quality of the radiographic image. The two main techniques relevant with this study are explained and analysed in the following sub-sections.

Grid Technique

Grids are used in radiography to protect the image detector from scatter radiation. Scatter radiation degrades the quality of the image and may lead to loss of anatomical detail and information (Sherer et al., 2006). Anti-scatter grids are made up of parallel radio opaque strips with a low-attenuation material interspacing the strips (Sherer et al., 2006). The most commonly used interspaced materials are aluminium and carbon fibre (Court & Yamazaki, 2004). The main function of these anti-scatter grids is contrast improvement. According to Carlton & Adler (2006), the most effective way to see how well a grid is performing is by measuring the contrast improvement factor. The contrast improvement factor measures the ability of a grid to improve contrast. This factor is affected by the volume of tissue irradiated and by the kV. If the amount of scatter radiation increases, the contrast of the image will be reduced, therefore reducing the contrast improvement factor. This is calculated using the following formula:

K= Radiographic Contrast with the grid/Radiographic contrast without the grid

(Carlton & Adler, 2006, pg. 263)

The higher the contrast improvement factor the higher is the contrast improvement. However, Court and Yamazaki (2004) argue that since contrast can be digitally altered in digital radiography, it is best to calculate the signal-to-noise ratio (SNR) of the image. This is especially useful in cases where there is low object contrast.

The interspaced material separating the lead grid lines is also very important in monitoring the functionality of a grid. In the study performed by Court and Yamazaki (2004) it was concluded that aluminium has a higher atomic number than carbon fibre and so it absorbs more low energy scatter radiation. However, aluminium also absorbs some of the primary photons therefore increasing patient dose. Alternatively, carbon fibre absorbs less primary radiation than aluminium (Court & Yamazaki, 2004). Grid ratio is also an important factor to consider in improving image quality especially image contrast. The grid ratio is obtained by dividing the height of the strips by the strip separation. As the grid ratio affects the rate of scatter to that reaching the detector it is instrumental in improving image contrast (Dendy & Heaton, 2003).

There are principally two types of grids, linear grids (parallel grids) and focused linear grids (Fauber, 2009). Both types have their own advantages and disadvantages. Parallel grids are made up of linear lead strips with low-density material interspacing them and are parallel to each other. This variety of grids produces grid cut-off at lateral edges since they do not coincide with the oblique divergences of the beam (Dendy &Heaton, 2003; Fauber, 2009). It is also essential that these grids are positioned correctly, perpendicular to the central ray of the primary beam. If this is done incorrectly, there will be grid cut-off and the lead strips will absorb a lot of the primary beam which will show up on the image (Dendy & Heaton, 2003). This will result in image deterioration and in the patient receiving an extra dose of radiation when repeating the exposure. The focused grids, however, are designed in such a way that it allows the lead strips to be gradually angled moving away from the central axis. Although these grids are designed to eliminate the cut-off on the lateral sides, they still have to be used at a specific focus to image distance (FID) depending on the type of grid being used (Dendy &Heaton, 2003).

Although grids are used to improve image contrast and reduce scatter reaching the detector, this is at the expense of a high radiation dose to the patient. This happens because the mAs has to be increased when using the grid. This is necessary in order to compensate the primary beam photons absorbed by the grid (Carlton & Adler, 2006).

Air-gap Technique

The air gap technique is an alternative technique used to reduce the amount of scatter reaching the detector. By employing an air-gap technique between the patient and the image detector, the energy of the scattered photons decreases especially in the first tens of centimetres due to the large divergence of the beam (Ball & Price, 1995). The primary radiation is not affected or reduced, since at this stage the primary beam is almost parallel to the detector (Ball & Price, 1995). When the air-gap technique is used, the object to image distance (OID) is increased, which may produce some magnification (Sherer et al., 2006).

Anti-scatter techniques are important in reducing low energy radiation reaching the detectors. However, the primary beam should not be deflected or disrupted so that the image acquisition and image quality is not affected (Fauber, 2009). When the grid technique is employed, the grid lines are unable to discriminate between the primary radiation and the scattered radiation and so this could lead to grid cut-off and ‘ grid lines’ may appear on the image (Maynard, 1981). Maynard (1981) argues that with the use of an air-gap the image quality and diagnostic quality of many projections improves. A study by Karoll et al. (1985) analysed the patient dose when the air-gap was employed compared to when the grid was used. In this study the air gap was employed in a digital subtraction examination. Karoll et al. (1985) reported that by using the air gap technique the mA could be lowered without losing spatial resolution. The results of this study were remarkable as the air gap technique allowed 25% to 88% reduction on the mA without increasing the kV or the time of exposure (Karoll et al., 1985). This meant that patient dose was reduced since the mA was lowered and so the patient was irradiated less. Although this study is 25 years old, it is still valid since in direct digital radiography, windowing has given the radiographer the possibility to reduce the exposure factors to a certain limit while still obtaining a good diagnostic image. This means that patient dose could be lowered.

Both grid and air-gap technique were studied and compared to assess patient dose by Kottomasu and Kulms (1997). The authors concluded that the air-gap improves musculoskeletal digital imaging without an increase in skin entrance dose. According to Kottomasu and Kulms (1997), this happened since the scattered photons had less energy once diverged by the patient; they were deflected and did not have enough energy to reach the image detector (Kottomasu & Kulms, 1997). Barall (2004) also suggested that when employing the air-gap technique the radiographer should apply inverse square law by increasing the SID and applying tighter collimation. This will ensure the highest decrease in patient dose possible (Barall, 2004). The increase in SID could enable a better use of the air gap while reducing magnification by keeping the source to object distant (OID) constant. In relation to the horizontal beam lateral hip projection, there is a reduction in dose and a good diagnostic resultant image when compared with the grid technique (Barall, 2004). Trimble (2000) concluded that imaging the thoracic spine without a grid was possible in children and adults of small size. In this study a significant dose reduction was noted and therefore on this basis, imaging the hip laterally using a horizontal beam and applying the air-gap technique instead of the grid may also result in a reduction of patient dose as opposed to using the grid technique.

Digital radiography

Radiography has been revolutionised and developed throughout the years from screen film (SF) radiography a high quality digital system has evolved (Oakley, 2003). With the introduction of digital imaging systems, image quality characteristics have improved. The process of image formation in DR is similar as in SF. The image is first generated, then processed, archived and presented. Instead of films, DR uses detectors which when exposed to x-ray radiation absorb this irradiated energy which is then transformed into electrical charges, recorded, digitized and configured into different grey scales (Dendy & Heaton, 2003).

The grey scales presented on the produced image represent the amount of x-ray photons absorbed by the detector. A big advantage in digital radiography is image manipulation post-processing. While viewing the image, the radiographer can zoom in or out, change the greyscale as well as use measuring tools. Another great advantage of DR over SF is that images can be stored safely and archived. This solves the problem of films being lost and enables future reference of the images (Carlton & Adler, 2006).

There are two types of digital imaging systems: computed radiography (CR) and direct digital radiography (DR). In computed radiography imaging plates containing photostimuable crystals are used, which absorb the x-ray energy and store it temporarily (Körner et al., 2007). Processing involves scanning the detective layer pixel by pixel using a high energy laser-beam of a specific wave-length. Since the exposed photon energies are only stored temporarily in the detective layer, the read-out process should start immediately after exposure. This is mainly because the amount of energy stored in these crystals decreases over time. Although this is a big step from screen-film (SF), spatial resolution in CR may decrease if viewing monitors are not of the appropriate resolution (Körner et al., 2007).

Direct digital radiographic systems use a photoconductor directly converting x-ray photons to electrical charges, once the photons are absorbed. The most common material used as a photoconductor in industry is amorphous selenium. This material has a high intrinsic spatial resolution. However, the material of the detector does not affect the pixel size, matrix and spatial resolution of the detector (Dendy & Heaton, 2003). These are affected by recording and read out devices used. Therefore image processing in DR is as important as in SF and CR. In DR image processing is used primarily to improve the image quality by removing technical artefacts, optimising the contrast and reducing the noise (Dendy & Heaton, 2003).

Radiation Dose

The transition from SF to DR has also changed the radiation dose that the patient gets from an x-ray exposure. Radiation dose is the amount of radiation absorbed by the patient due to a radiation exposure (Carlton & Adler, 2006). In SF radiography the dynamic range of the receptor (film) is relatively low and so it only detects specific exposures that lie within its parameters. However, in DR the digital receptor can detect a wide range of exposures. This means that a slightly underexposed or overexposed image is acceptable since image quality can be altered using windowing. Therefore in DR the radiation dose could be kept relatively low when compared to SF while still producing a good diagnostic image. This could also work the other way when patients are overexposed to radiation due to the wide dynamic range of the receptors. The ALARA concept is based on the theory that there is no “ safe” dose of radiation using any kind of irradiation or radioactive material (The Ionising Radiation [Medical Exposure] Regulations, 2000/2007

& The Medical Exposure Directive 97/43/Euratom). In this way individual’s internal and external exposure to radiation is kept to a minimum. This principle does not only address radiation used in medicine but also social, technical and economic considerations of use of radiation. This principle also takes into consideration the time of exposure of radiation, filtration, and appropriate materials selected to minimise radioactivity depositing on surfaces. This also ensures the safe disposal of materials containing radioactivity such as needles used in nuclear medicine (The Ionising Radiation [Medical Exposure] Regulations, 2000/2007, & The Medical Exposure Directive 97/43/Euratom).

The use of ionising radiation should be monitored and used carefully to ensure as low a dose exposure as is reasonably achievable to the patient while at the same time producing an image of high diagnostic quality.

Relative Literature

The latest literature reviewed in relation to this dissertation was that of Flinthman (2006) who assessed thirty-five horizontal beam lateral hip radiographs for image quality. Nineteen of the cases were performed using the air-gap technique whereas sixteen using the grid technique. Several radiologists and radiographers were asked to evaluate the images. It was found that the air-gap was of higher image quality than the grid technique (Flinthman, 2006). In Flinthman’s study several persons were asked to evaluate an uneven number of cases that were meant to be compared regarding the technique used to obtain the radiographs. According to Flinthman (2006) it is more important to have a small group of people evaluating the radiographs. This is because the results could be more specific and more reliable (Flinthman, 2006). A limitation of this study is that Flinthman (2006) did not use the same subjects in both techniques to achieve his results and so it is harder to attain valid and conclusive results that could be applied in a clinical setting.

A similar study comparing the grid and air-gap technique was conducted by Persliden and Carlsson (1997). Persliden and Carlsson (1997) studied scatter reduction using the air-gap and the grid technique. This study investigated the effect of the air-gap technique over the imaging plate and demonstrated the positional variation of scattered radiation (Persliden & Carlsson, 1997). The authors concluded that by using the air-gap technique, the patient irradiation was lowered. Persliden and Carlsson (1997) argued that even field size and patient thickness greatly affected the use of the air-gap.

As well as Persliden and Carlsson (1997), Trimble (2000) looked and assessed image quality of lateral thoracic spine radiographs and chest radiographs. These examinations were both done using the grid technique and the air-gap technique. Trimble (2000) found it important to have a large sample of subjects while keeping the specialists evaluating the images small. Trimble’s study resulted in the air-gap being better for high image quality than the grid.

Similiar to this study, Goulding’s study (2006) who looked at image quality in lateral hip radiography when using both grid and air gap technique. The radiographs were obtained from the accident and emergency department Goulding (2006) worked in, where radiographers performed lateral hip shoot through examinations using their preferred air gap or grid technique. Goulding (2006) took a sample from the recorded examinations of both techniques. The researcher excluded examinations with an exposure of 100 mAs or more as well as any duplicate patient numbers due to re-assessment as well as those examinations that used both air gap and grid technique in the same examination as this signified a very large patient. Goulding (2006) compared the sampled gird and air gap radiographs after reporting radiographers evaluated five areas on each radiograph, chosen by the researcher. The radiographers had to score each area from one to five where one is poor and five is optimum. It resulted that the air gap technique had improved image quality more than the grid technique. A limitation of this study was, however, that the patients used to test for both techniques were not the same, and so this could have meant that the results were not totally reliable since patient size and exposure factors were not constant but varied depending on each examination.

Conclusion

The literature reviewed in this chapter has explored furthermore the roles of the air-gap and grid technique in imaging. It has also analysed the effect of scatter radiation and ways to reduce this in order to improve radiographic image quality while limiting the radiation dose to the patient as much as possible. Several studies were reviewed and analysed and will help to improve this experimental research. Some studies that are similar to this study were reviewed and discussed.

In the next chapter, a description of the research design used in this study will be presented.