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Assessment on Digital Imaging Enhancement for Radiographic Interpretation

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Assessment on Digital Imaging Enhancement for Radiographic Interpretation

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ABSTRACT

In recent time digital imaging systems are the most commonly utilized technology in the field of radiology. The screen-film radiography systems are almost replaced by digital radiography. In which the image quality should be optimized while lower radiation dose is maintained according to the properties of the specific imaging system. Therefore, it is essential to regularly investigate image quality to ensure correct and accurate image interpretation assessment. This research is aimed to assess the factors that influence image quality and to recognize the different evaluation methods and their corresponding approaches that are used for system performance. Resolution describes the ability of medical imaging process to discriminate adjacent structures in organ tissues being examined. Signal from detected photon should be recorded with sufficient resolution in space, intensity and possibly time to produce a digital image that enables a medical interpretation of tissue structure and function. The anatomical and physiological characteristics of the region being imaged are considered to be the intrinsic factors of image contrast, which are called intrinsic, subject, object, or patient contrast. Low intrinsic contrast tissues such as breast tissues have very subtle differences in composition. In radiography, the physical properties of atomic number, physical density differences among different tissues and patient thickness influence intrinsic or subject contrast. Imaging methods and techniques are the second major factor which control image contrast. Will be more appropriate to select careful exposure techniques for specific tissues and for certain purposes greatly enhances image contrast to obtain the desired information. The only way to optimize image quality parameters while maintaining low radiation dose is to deeply understand the effects of these parameters on each other, the influence factors and their impact on the radiation dose for each different digital radiographic systems.[5]

Keywords: Assessment, Image Enhancement, Radiology, Digital, Technology

1. INTRODUCTION

In advent of technology digital images have vital advantages in health services. Image quality has been improved and patient radiation dose reduced by the introduction of digital imaging systems including computed radiography (CR) and digital radiography (DR). In addition, digital imaging modalities have revolutionized communication between radiographers, radiologists, and physicians. However, CR and DR also have some limitations such as higher initial cost, particularly for DR. In addition, consistent feedback that is required to obtain optimal acquisition may not be available for technologists. Potential increase in radiation dose, due to wide dynamic range of digital systems, is also a potential drawback of CR and DR. Patients may be overexposed with more radiation than is required for a diagnostically sufficient image. Diagnostic information may be suppressed as a result of suboptimum image processing.

Therefore, it is essential to regularly investigate image quality to ensure correct and accurate image interpretation. No clinical detector can perfectly absorb all the incident x-ray photons. Some x-ray photons pass straight through the x-ray detector. Others that are absorbed may be re-emitted and exit the detector. As a result, there is loss in primary information. Additionally, noise arises from the amorphous array and readout electronics of the detector. These factors degrade image quality.4 Reliable diagnosis requires regular maintenance of the technology employed and alongside regular clinical evaluation of image quality. T e criteria of optimum image quality should be determined and recognized. The purpose of this review is to provide an overview of the parameters and their factors that influence image quality and to recognize the different evaluation methods and their corresponding approaches that are used to assess image quality and system performance.[3]

There are numerous parameters that characterize the quality of digital images. Resolution, noise, and artefacts are the main parameters of image quality. Some studies include blur factors which relate so far to the spatial resolution. Resolution describes the ability of medical imaging process to discriminate adjacent structures in organ tissues being examined. Signal from detected photon should be recorded with sufficient resolution in space, intensity and possibly time to produce a digital image that enables a medical interpretation of tissue structure and function.

Three main categories of resolutions
- Spatial resolution (space)
- Contrast resolution (intensity)
- Temporary resolution (time)

The Spatial Resolution

Spatial resolution refers to the ability of imaging system to detect and discriminate small objects that are close together. The size of pixels and the spacing between them (the pitch) define the maximum spatial resolution. The smaller the pixel sizes the higher the spatial resolution. However, this is not always true because the spatial resolution is influenced by other causes such as blur factors. Image processing alters image spatial resolution however the image noise is excessively increased. Zooming or targeting and scanned field of view functions influence spatial resolution.

Measurement methods including the point-spread function (PSF), line spread function (LSF) and the modular transfer function (MTF), are used to quantify and evaluate spatial resolution. Spatial resolution is affected by four blur factors, namely subject blur, geometric blur, motion blur, and receptor blur.13 Image blur refers to the element of blurring to boundaries in the object (patient). Sharp image describes the well- defined boundaries of the object (patient). Subject blur is caused by object shape or/and structure composition. This factor is also called object blur. Geometric blur results from the geometry of the image- construction procedures. The main influences of this factor are focal spot size of the x-ray tube, the distance between the x-ray source and patient and between single elements of the detector, they are smeared out and their contrast is reduced unless they are inherently high contrast objects. For example, when micro calcification is smaller than an element, it may be recognized as a calcification since its attenuation properties are so different from the other tissue in the element.

Contrast Resolution

Contrast resolution refers to the ability of an imaging system to discriminate objects with small density differences and/or differentiate small attenuation variety on the image.2 Contrast resolution explains how well the image discriminates subtle structures in organs being examined. Contrast resolution can be inherited by recording the information of interest with sufficient intensity resolution to discriminate the contrast details of interest. While the first step of digitization, sampling in space, affects the spatial resolution, the second step, quantization in signal Intensity, influences the contrast resolution or the gray- scale bit depth.13 Contrast resolution is sometimes called tissue resolution. If there are two small objects with large difference in densities, the area between them is considered as high frequency or high contrast region. Conversely, low contrast region refers to the area between two small objects with small difference in densities. Contrast resolution is affected by tube collimation, number of photons, noise, scatter radiation, beam filtration, detector properties and algorithmic reconstruction used. Image contrast depends on subject contrast, detector contrast and displayed contrast.

The anatomical and physiological characteristics of the region being imaged are considered to be the intrinsic factors of image contrast, which are called intrinsic, subject, object, or patient contrast. Low intrinsic contrast tissues such as breast tissues have very subtle differences in composition. In radiography, the physical properties of atomic number, physical density differences among different tissues and patient thickness influence intrinsic or subject contrast. Imaging methods and techniques are the second major factor which control image contrast. Selecting careful exposure techniques for specific tissues and for certain purposes greatly enhances image contrast to obtain the desired information. For example, low kVp and small amounts of beam filtration are preferable in mammography to discriminate subtle differences among tissues. In chest radiography, however, high kVp and large amounts of beam filtration are used to demonstrate the wide range of varying tissues densities (lung, bone tissues). This technique helps in detecting lesions of increased physical density in the under the ribs. Introducing enhancement material or medium into the body improves image contrast by altering subject contrast.

Contrast media changes photon attenuation properties from those of the surrounding tissues and therefore provide signal differences. A detector's characteristics play an important role in producing contrast in the final image. Detector contrast is determined principally by how the detector detects and converts the energy into the output signal. The dynamic range of the detector influences the contrast resolution of image. The dynamic range of CR and DR, which is the ratio of the maximum to minimum input x-ray intensities incident on the detector surface, ranges from 1,000:1 to 10,000:1 compared with the dynamic range of film screen radiography which ranges from 10:1 to 100:1

Noise Resolution

Noise is produced by the statistical fluctuation of value from pixel to pixel. Noise is recognized by a grainy appearance of the image. It is also characterized by a salt and pepper pattern on the image.6 Noise is un-useful information. The noise level is explained by the standard deviation, a measure of how spread out the pixel's values are. The lower the standard deviation, the higher the accuracy of the average pixel value. Noise images relates to the number of x-ray photons that are logged in each pixel (for DDR) or in each small area of the image (for CR and IDR). Goldman6 categorized the noise sources into three types, namely quantum noise, electronic or detector noise and computational or quantization noise. Noise originates from internal sources mainly image receptors which contain what is called electronic noise. Detector or receptor noise is produced because of non-uniform response to a uniform x-ray beam. This type of noise has fixed correlation to locations on the receptor, therefore it is called fixed pattern noise. Fixed pattern noise can be largely eliminated in digital imaging systems through post processing stages. Additionally, defects in the receptor's elements which may occur during the manufacturing process form unrelated structure in the image.

Structured noise originates from different causes which creates unwanted signals or features on the image. Variations in pixel-to-pixel sensitivity and linearity, dead pixels and detector-response non-uniformities are the main causes of structure noise, particularly in DR. Conversion noise occurs because of the fluctuations of the generated energy per detected photons. Conversion noise which is also called instrumentation noise can be reduced by utilizing higher-intensity scanning laser in CR detectors and brighter phosphor screens in indirect flat-panel detectors to collect and generate more secondary energy carriers and hence improve QDE. In addition, lowering the number of conversion stages of process can also reduce conversion noise.

Quantization noise is another source of noise which occurs during the digitization process, translating analogue output voltage of detectors to discrete pixel values (grayscale values). The range of these values is determined by bits, binary on-off channels. Detectors of 10 to 14 bits (1024 to 16,384 digital values) are recommended to minimize quantization noise in CR and DR systems.2 Noise is also produced by scatter radiation which reduces subject contrast and decrease signal to noise ratio (SNR) and consequently degrades image quality. Using grid in CR and DR reduces scatter radiation and consequently reduces noise effect. However, the signal (incomplete transmission of the primary radiation by the grid) is also reduced. [5]

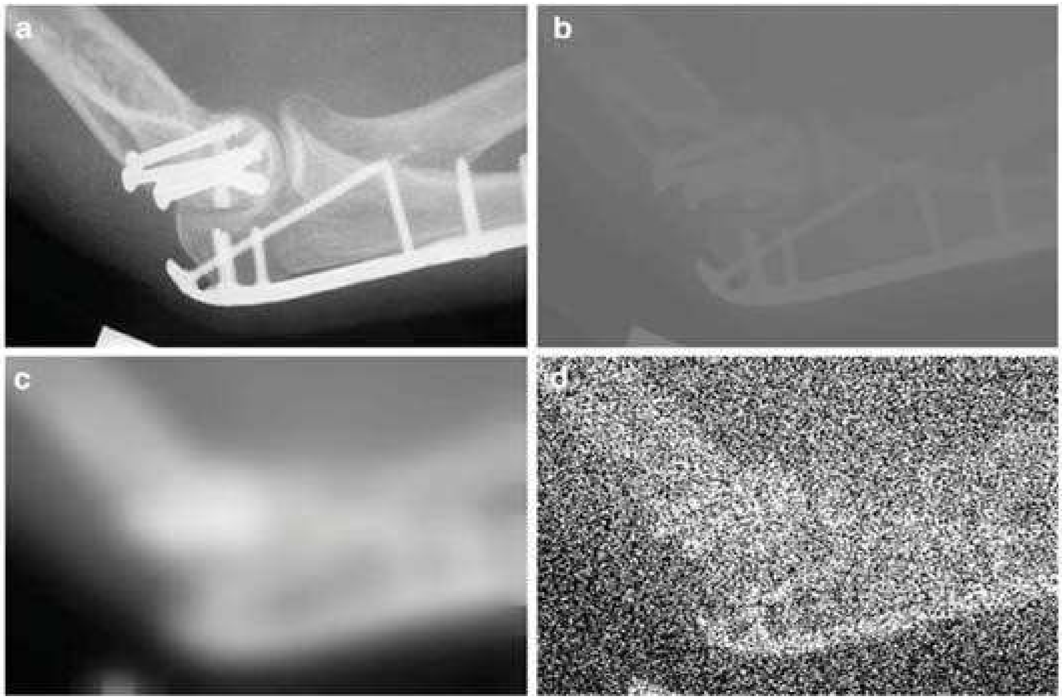

Figure 1: Optimum image quality has adequate resolution and contrast, and a low noise level, as demonstrated in image (a). Image (b) has high spatial resolution and low noise, but it has almost zero contrast. Image (c) has low noise and high contrast, but very poor spatial resolution. In image (d) has high spatial resolution but very high noise level which destroyed the image contrast. [2]

2. BACKGROUND TO THE STUDY

The term “image quality” is often used to describe the psychophysical properties of the imaging system, but there is no criterion related to image quality. According to Kundel proposed three ways of assessing diagnostic image quality: by visual inspection of the image, measurement of diagnostic performance, and physical measurements made on the image or imaging system (Fig. 2). As the psychophysical phase in the radiological diagnostic process includes “image store”, “image display”, and “image perception” psychophysical property shows the results of both physical measurements and visual inspection of the image in terms of the diagnostic image quality. Thus, sensitometric and the image transfer characteristics of the system represent psychophysical property of the system. Psychophysical property is a part of the overall image quality and eventually related to the diagnostic performance of the system. [5]

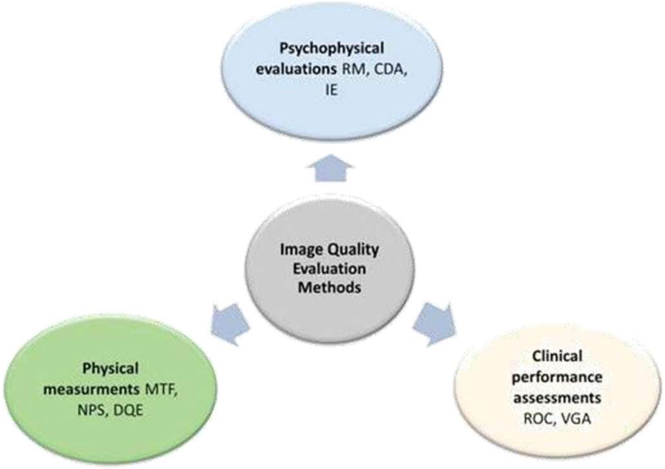

Figure 2: The Types of Evaluation Methods of Image Quality

Optimum image quality relies on the balancing of the image quality and patient dose and depends on the region being studied and case being examined. To optimize image quality, image quality parameters mentioned previously should be manipulated and altered according to the purpose of examination with respect to the patient dose. Moreover, eliminating or limiting the effects of image degradation factors are also essential in optimizing image quality. Optimal image quality is achieved at the lowest possible patient radiation dose. The high flexibility of CR and DR increases the opportunity of image quality optimizing and radiation dose lowering. [5].

The minimum level of image quality and radiation dose should be determined based on diagnostic purpose. It is essential to recognize the parameters that affect radiation dose and their influences on image quality. Exposure factors including mA, time and kVp are the most important factors that control the radiation dose to the patient. The other factors that also affect radiation dose are patient size and detector properties. Reducing mAs decreases radiation dose and consequently decreases SNR as the noise is associated with lower radiation dose. Lower radiation dose deteriorates contrast resolution of the image. High noise level images increase the risk of diagnostic details loss.

Lowering the kVp is essential to increase x-ray attenuation and consequently the contrast resolution of structures is improved. Lower voltage increases DQE of the detectors of digital system. As a result, image quality can be improved. In CR and DR, Lower kVp techniques are more likely to improve SNR and hence the contrast resolution of image. However, low kVp techniques may increase radiation dose and image blur as a result of time increasing. Uffmann, et al. in their study found that selecting 90 kVp demonstrates the anatomic structure superior than that of 120 and 150 kVp without increasing the radiation dose to the patients. Changing tube voltage from 102 to 133 kV did not significantly improve contrast resolution of CR and DR. However, higher kVp should be used for thicker body organs to optimize the contrast resolution of the image.

The failure of attention is one source of error in radiology. Because humans cannot process everything in the visual field, attention is drawn to objects that have prominent intrinsic features. This is referred to as bottom-up processing. Color, motion, orientation, and size are among the attributes that guide visual search and are called “preattentive,” meaning that they are perceived rapidly without any conscious effort. In top-down guidance, the searcher has a representation of a target in mind and directs attention to items that have those features. Learning, memory, attention, and expectation shape this perceptual process. Scene guidance is learned and is based on the understanding of a scene's contents and layout.

3. FINDINGS AND DICUSSION

Although digital image consists of a matrix of numbers or digits that when processed by a computer will produce an image on a monitor. Digital information is stored as bits, with 8 bits forming a byte that represents a value or character. Digitization is the process of acquiring or converting analogue images into a digital format. Many imaging modalities acquire the image initially in this format, for example with CT, MR and ultrasound. All images today can be converted into digital format. The advantages of digital imaging are the ease of storing images and the ease of transmitting images and manipulating the images during image interpretation. You no longer have to rely on finding the radiographs! It is important to be aware of the disadvantages. Long term storage of digital images is especially expensive. Given these challenges, there is no doubt that as computer processors and storage devices become less expensive, many hospitals in developing countries will use digital imaging in the future.

Each medical image is stored as a file on the computer. The file can be compared to the X-ray packet of a conventional radiograph. The files vary greatly in their size or number of bytes they contain. Chest radiographs when in digital format consist of 2 Mbytes (2 million bytes) while an ultrasound or CT scan may be 10 times smaller at 200 Kbytes in size. Generally plain analogue radiographs when in digital format have much larger files than more modern imaging investigations, such as ultrasound or CT imaging. A contrast detail analysis (CDA). This method provides quantitative evaluations of low contrast and small detail measurement of medical images. CDA originated from the theory of signal detection which implies that low contrast-detail detectability is related to internal signal-to-noise ratio of the observer. The main assumption of this theory is that noise from different sources interferes with sensory stimuli to the observer. The ability of imaging system to visualize small objects which are of very low contrast describes low contrast-detail detectability of the system. Low contrast-detail detectability can be assessed by measuring the ability of observers to detect the smallest objects which have varying contrast differences with the background.

CDA is an approach to describing the image quality in terms of detail (drilled holes of varying diameter) and contrast (varying depth).Low contrast-detail detectability Implies that the detectability of details increases with increasing the size of objects and/or contrast between the objects and the background. For example, when the objects' size increases while keeping the contrast differences the same, the detectability will increase. The detectability will also increase when the contrast differences between the objects and the background increases while maintaining object size. In other words, the large objects can have lower contrast than smaller objects for the same detectability performance. Human observation is mostly involved in the process of evaluation to visually measure contrast-detail on the image.

Therefore, this method is considered a subjective evaluation. Observers are asked to score what they can detect on the phantom image on the first three rows and to score and locate (in which corner the object is) what they detect on the rest rows in order to limit false positive score. By plotting the smallest visible diameter (Cj) against the smallest visible depth (Di), for all rows i, a contrast- detail curve is obtained. The next equation is used to calculate inversed image quality figure inverse (IQFinv).

The greater value of the IQFinv, the better is the low contrast detectability. Where Cith, is threshold contrast Dj,th, is threshold detail CDA method provides quantitative evaluations of low contrast and small detail measurement of medical images. Therefore, it is considered straightforward and direct method of image quality assessment. Moreover, low CDA studies consider the whole processes of imaging systems such as detector design, x-ray parameters, image acquisition and processing, image post processing, and image displaying. Therefore, CDA is selected to provide insightful understanding of CR and DR systems. A recent study by De Crop, et al. investigated the correlation of low contrast-detail performance measurement and clinical image quality assessment in chest radiography.

The findings of this study suggested that there is significant correlation between physical (low contrast-detail measurements) and clinical evaluation methods. The researchers concluded that the CDA method is relevant for image quality optimization. While this method was based on a phantom, it does not require volunteer patients. Therefore, the evaluation method of CDA can be used to compare and contrast the image quality of different systems. [3]

The amount of radiation emitted from X-ray units while taking X-rays is photon radiation, and these photons are known as X-rays. They are generated when high-energy electrons, accelerated by a high voltage potential difference, strike a target in the X-ray tube and their energy is converted to photons which radiate out from the target. The energy of the electrons, and hence the resultant photons, is expressed in terms of thousands of electron volts (keV). Photon energies used in diagnostic radiology are in the range 20 keV to 150 keV. When a patient is exposed to an X-ray beam a large amount of radiation is also produced in other directions. Much of the radiation entering the patient is scattered and exits the patient in all directions.

Some of the photon energy is lost during the scattering process, so the scattered photons are of a lower energy than the primary photons. For most radiographic procedures only about 1 to 10% of the primary beam emitted from the X-ray tube actually interacts with the detector system. (This excludes the photons absorbed by the casing and collimators of the X-ray tube). The rest of the energy is lost due to scatter or absorption in the patient. With newer, and more efficient, detector systems, less radiation is required to produce diagnostic quality images. This reduces exposure to the patient.

Spinal Trauma

There is a wide and complex spectrum of injuries to the spine. Radiographs are used to show the of bony injury and assess whether a fracture or fractures are “stable” or “unstable”. It is important that, in a case of suspected spinal injury, the radiographs are obtained with the minimum amount of patient movement. A stable fracture is one that can be expected to retain its position without immobilization. An unstable fracture is one that, without immobilization, may deteriorate in position thereby causing progressive neurological compromise. The spine is considered to be made up of three functional columns shown in (figure:3). If two or more of these columns are involved in trauma then the injury should be considered to be potentially unstable. Remember that trauma to the columns may cause a combination of bony (fractures) and soft tissue injuries (ligamentous/disc disruption), of which the latter is not seen on the radiograph. With major trauma it is not unusual to sustain more than one fracture. Therefore, it is prudent not to stop looking at the spine radiographs when the first fracture is identified. CT, if available, is an excellent method of demonstrating the presence and extent of spinal fractures.

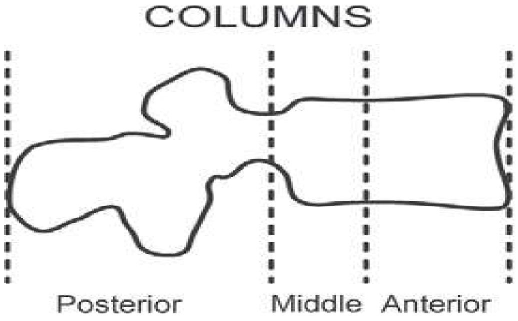

Figure 3: Line diagram showing. The functional columns of the spine. Disruption of two or more columns results in an unstable fracture.
(Modified from Lee Rogers Radiology of Skeletal Trauma 2nd Ed, Churchill Livingstone 1992)

Figure:4 lateral view of cervical spine with the three lines (arcs) that should be reviewed when assessing a lateral radiograph of the cervical spine in trauma.[2]

Alignment of Spinous Processes

The spinous processes should lie in a straight line on the AP view and be equidistant on the lateral view. Splaying of the inter spinous space on the lateral view will indicate ligamentous disruption and a degree of subluxation. Loss of alignment on the AP view suggests unilateral problems with abnormal rotation at the injured level e.g. unilateral facet dislocation.

Vertebral Body and Disc Space Height

The vertebral bodies should have a relatively uniform square/rectangular shape and the disc spaces be of uniform height.

- Loss of height of a vertebral body indicates a compression fracture.
- Widening of a disc space indicates severe injury with disruption of the disc.
- Narrowing of the disc space may be due to chronic disc damage, and is common in old age. However, subluxation of the vertebrae must be excluded when there has been an acute injury.

Film-Screen Contact Test-2

It is essential that images be obtained with good film-screen contact. Poor film-screen causes loss of information which may cause inaccurate pattern recognition. The film screen contact test tool is readily available but a bit expensive. To perform the test place the contact mesh tool (wire mesh encased in perspex) on the top of the suspect cassette containing an unexposed film. Centre to center of cassette, collimate to cover cassette. Make sure that table on which the cassette is placed and the central ray are at right angles. Expose the test tool using approximately 55-60 kVp and 4 mAs (for 200 speed system) and 100cms Focal film distance. Process the film and view at a distance of 150- 180 ems to evaluate the sharpness of the wire mesh. Poor film-screen contact usually occurs when a cassette gets dropped when excessive force is used during handling.

Collimator-beam alignment test

This test should be done at least every month to check proper alignment of collimator and primary beam as daily use of the collimator contributes to poor alignment of the light beam and primary beam. This in turn causes suboptimal positioning as it may be difficult to accurately centre as per routine techniques.

Factors relating to contrast and sharpness of the image

Contrast refers to the difference in density (film blackening) of two areas. To put it simply an image that only has two densities/tones will have high contrast as it only has a short scale such as a black/white image. Long scale contrast occurs when the combinations will reduce dose but one may not see fine detail. The deciding factor should be the reason for the examination paying attention to ALARA careful positioning should be practiced with appropriate exposure factors to produce an image with film blackening within the useful density range.

Factors influencing mAs selection include FFD as per the inverse square law, speed of imaging system, collimation of the primary which reduces scatter/secondary radiation thus contrast is improved, and use of secondary radiation grids. Quality criteria for each radiologic examination are used to evaluate image quality of specific examination. These criteria, developed by professional radiologists, technologists and physicists, describe physical and anatomical characteristics of image appearance and dose level. For example, chest examination criteria are used to evaluate chest images by letting experienced radiologists and technologist to determine the level of fulfilling these criteria in that image.[5]

This method has several advantages which make it preferable, but again it still has some limitations. Several factors make this method useful. First, almost all process components of imaging system which control image quality are considered in the evaluation procedures of VGC. These components include image processing, recording, post processing, and reading by expert radiologist. Therefore, the practical validity of this method is considered high. Second, VGC is based on the visualization of clinically relevant available standards to evaluate image quality. The conducting process of VGC is similar to that of daily clinical situation. Third, this evaluation method has easier procedures and makes for less work than some other methods such as ROC. Furthermore, the required time that the observers are required to read the images is reasonable and therefore there is no real barrier with this regard to have participants. This method can also be used to compare the performance of different imaging modalities in terms of image quality and dose level.

The limitations of these methods include false positive fractions of limited or no clinical relevance. Furthermore, fulfilled criteria that are judged by the observer may correspond to an unacceptable image. Additionally, there are difficulties in analyzing the uncertain data from VGC. Hence, the underlying reasons of the uncertainty cannot be identified whether these reasons are related to poor image quality, observer influences or other factors. In addition, VGC suffers from the subjectivity of observers which minimizes its reliability. According to the above discussion, evaluation methods related to pure statistical measurement such as DQE has a low validity when used to measure the clinical performance of an imaging system unless complete imaging procedures, including image processing, display and the response of the observer, are considered. However, DQE is the most effective evaluation method for objectively assessing the performance of the detectors of imaging systems. Even though, the reliability and validity of DQE is high in providing accurate measurement of the ability of information transfer, its validity is low in assessing an entire imaging system.

4. RECOMMENDATION AND CONLUSION

The paper explore the good imaging concept and radiation protection in radiological sphere. The reason for monitoring is to ensure that the practices being followed by the workers in their daily routine are safe and do not result in high doses being received. [1] Although the radiological process in medical diagnostic tasks may be complicated, the radiological diagnostic process for approximal caries seems to be relatively simple. There is a clear correlation between psychophysical properties of the radiographic system and diagnostic accuracy obtained from it. It implies that an improvement in the physical image quality leads to increased diagnostic performance to some extent in the approximal caries diagnosis. Rapid film interpretation speed can also be a source image disruption.

The relationship between the quality parameters of digital radiographic images including resolution (spatial resolution and contrast resolution), noise, and artefacts is complicated, meaning that there is a trade-off between them, improving one parameter may deteriorate another. Hence, optimizing these parameters is not a simple task. Optimizing image quality parameters in regard to radiation dose make it a more complicated task. Additionally, the effect levels of these parameters on image quality of different digital radiography systems and units are not exactly the same even though they share the principles of image quality parameters. The only way to optimize image quality parameters while maintaining low radiation dose is to deeply understand the effects of these parameters on each other, the influence factors and their impact on the radiation dose for each different digital radiographic systems.

Each of the available evaluation methods has its own advantages and limitations. Therefore each evaluation method should be utilized and employed according to its aptitudes to improve image quality and imaging process. Intensive training session that would address acquisition of images, analysis of images, simple troubleshooting techniques, and it should include a review of the fault tree of actions to be taken if the artifact check produces unacceptable results it will have positive effect on the ability of radiographers to accurately interpret images such as plain musculoskeletal radiographic examinations.

Extrapolating this finding, it seems that providing such programs could be beneficial in reducing the risk of misdiagnosis. [7] Conclusively, the conventional Radiography is evidently the last of the radiology modalities to embrace and incorporate digital technology. By their tremendous impact on the image quality and the workflow, digital radiography systems have become practicable alternatives. [8]

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