OPTIMIZATION OF DOSE AND IMAGE QUALITY FOR COMPUTED RADIOGRAPHY (CR) AND DIGITAL RADIOGRAPHY (DR) FOR CHEST, ABDOMEN AND LUMBAR SACRAL SPINE IN PAHANG

BY

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ABSTRACT

Optimization of dose in radiographic examinations is essential since the utilization of x-radiation have a related induced cancer risk. Further, the quality of images produced need to be maintained at an accepted diagnostic level. Thus, this study was conducted with the aim to provide guidance to the radiographers in ensuring best practises in producing radiographs for common radiographic examinations of acceptable image quality in digital radiography whilst minimizing radiation dose that could cause harmful effects. The study comprised of three phases. The first phase (pre optimization study) involved 90 respondents aged between 20 to 60 years and weighed between 60-80 kilograms that underwent AP abdomen, AP and lateral lumbar sacral spine and PA chest examinations. During this phase, technical parameters selected for 30 radiographs from each examination was left to the discretion of the radiographers. Kerma X_plus, DAP meter was utilized to evaluate the entrance surface dose (ESD) while CALDose_X 5.0 Monte Carlo was used to estimate effective dose. The second phase (experimental study) utilized an anthropomorphic phantom (PBU-50) and Leeds test object to compare image quality. Variation of technical parameters was utilized to find the best parameters to be adapted to patient AP thickness in the post optimization study. In the optimization study, 90 radiographs were produced with similar respondent's characteristics as the pre optimization study but utilizing the best technical parameter from the experimental phase with the lowest ESD and acceptable image quality. The image quality for pre and post optimization were assessed by two radiologists utilizing the modified criteria from the Commission of European communities on image quality. Inferential statistics indicated there were significant differences (p<0.05) between image quality and radiation dose for PA chest in HOSHAS and HTAA in the pre optimization study. Wilcoxon signed-rank test reflected that there were significant differences in image quality for pre and post optimization study with better image quality found in the post optimization for all four examinations. However significant differences in ESD were only found for AP abdomen and PA chest with a lower ESD being received by patients in the post optimization study. Tube potential (kVp), tube current-time, focus to film distance (FFD), usage of grid, automatic exposure control, additional filter and practice of radiographers were found to be associated with image quality and radiation dose. The study also indicated that the ESD received by the patient for post optimization study to be lower than all published data and that suggested by radiation regulatory bodies. Optimization of dose and image quality was achieved from this study by proper use of AEC with correct chamber selection, utilizing an appropriate kVp, correct FFD (115cm) and the use of 0.2mm added copper filtration.

خلاصة البحث

تعتبر عملية تحسين الجرعة في الفحوص الإشعاعية أمرًا مهماً، نظراً لوجود علاقة بين استخدام الأشعة السينية وأمراض السرطان. بالإضافة لذلك إن جودة الصور المنتجة يجب أن تحافظ على مستوى تشخيص مقبول. وقد أجريت هذه الدراسة بهدف توجيه مصوري الأشعة للقيام بالتطبيق الأمثل في انتاج الصور الشعاعية المتعلقة بالفحوصات العامة والتي تضمن صور ذات جودة مقبولة في مجال التصوير الإشعاعي الرقمي و بنفس الوقت تخفيض حجم الجرعات التي قد تسبب تأثيرات ضارة. و قد تضمنت الدراسة ثلاث مراحل، المرحلة الأولى (مرحلة ما قبل التحسين) تضمنت ٩٠حالة بين عمر ٢٠و٦٠ سنة و تراوحت أوزانهم بين ٦٠و٨٠كغ. و قد أجريت الفحوصات على المنطقة البطنية والمنطقة العجزية الفقرية القطنية والمنطقة الصدرية. واتضح من خلال المرحلة الأولى فإن المعلمات التقنية ل ٣٠ صورة من كل اختبار تركت لتقدير فنيي الأشعة. استخدم مقياس Kerma X_plus, DAP لتقييم سطح دخول الجرعة، بينما تم استخدام مقياس CALDose_X 5.0 Monte Carlo لتقدير الجرعة الفعالة. في المرحلة الثانية من البحث تم استخدام مجسم فانتوم (PBU-50) واختبار ليزر لمقارنة الجودة بين الصور. وقد تم استخدام تباين المعلمات التقنية لإيجاد أفضل المعلمات والتي تناسب سمك الصور لمرضى AP في مرحلة ما بعد التحسين. أما في مرحلة التحسين فقد تم إنتاج 90 صورة شعاعية بنفس خصائص المستجيبين كدراسة مسبقة للتحسين، ولكن باستخدام أفضل معلمة تقنية من المرحلة التجريبية والتي أظهرت أقل درجة من ESD وجودة مقبولة. تم تقييم جودة الصورة في مرحلة التحسين وما بعد من قبل اختصاصيي أشعة وذلك باتباع المعايير المعدلة للجنة الأوروبية المتعلقة بجودة الصورة. و قد أظهرت الإحصائيات الاستنتاجية في مرحلة ما قبل التحسين إلى وجود فروق معنوية($p < 0.05$) بين جودة الصورة و الجرعة الإشعاعية ل PA في HOSHAS و HTAA.كما وقد أظهر اختبار Wilcoxon وجود فروق معنوية في جودة الصور في مرحلة التحسين وما بعد التحسين وكانت أفضل صورة قد أنتجت في مرحلة ما بعد التحسين بالنسبة الفحوصات الأربعة. وقد أظهرت الدراسة فروق معنوية في ESD فقط بين AP البطنية و PA الصدرية مع انخفاض استقبال ESD من قبل المرضى في مرحلة ما بعد التحسين. وقد أظهرت الدراسة أن قناة (kVp)، وقناة التوقيت، ومسافة التركيز، واستخدام الشبكة، ومنظم التعرض التلقائي، والفيلتر الإضافي وممارسات الفنيين كان لها ارتباط واضح بجودة الصور والجرعة الإشعاعية. وقد أظهرت الدراسة أيضاً أن ESD التي تلقاها المرضى في مرحلة ما بعد التحسين استخدمت لتكون أقل من تلك المستحصلة من البيانات المنشورة ومن تلك التي تم اقتراحها من قبل هيئة التنظيم الإشعاعي. وفي الخاتمة فإن تحسين الجرعات وجودة الصور قد تحقق في هذه الدراسة بالاستخدام الأمثل ل AEC وذلك باختيار أفضل فجوة خلال التصوير الاشعاعي، وبالاستخدام المناسب ل kVp، و (cm115FDD)، وبإضافة mm0.2 من فلتر النحاس.

APPROVAL PAGE

I certify than I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Health Sciences (Medical Imaging)

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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It is my utmost pleasure to dedicate this work to my dear parents especially my mother and my family who granted me the gift of their unwavering belief in my ability to accomplish this goal, thank you for your support and patience.

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LIST OF ABBREVIATION

AEC	Automatic Exposure Control
Al	Aluminium
ALARA	As Low As Reasonable Achievable
AMFPI	Active Matrix Flat Panel Imager
AP	Anterior-Posterior
ASRT	American Society of Radiological Technologist
BaFBr	Barium Fluoro-Bromide
CME	Continuous Medical Education
CNR	Contrast-Noise Ratio
CR	Computed Radiography
CRCPD	Conference of Radiation Control Program Directors.
Cu	Copper
DAP	Dose Area Product
DDIR	Department of Diagnostic Imaging and Radiotherapy
DQE	Digital Quantum Efficiency
DR	Digital Radiography
EC	European Commission
ED	Effective Dose
ESD	Entrance Surface Dose
EXI	Exposure Index
FASH	Female Adult Phantom
FFD	Focus to Film Distance
FFDR	Full-field Digital Radiography
HKL	Hospital Kuala Lumpur
HOSHAS	Hospital Sultan Haji Ahmad Shah
HTAA	Hospital Tengku Ampuan Afzan
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IIUM	International Islamic University Malaysia
INAK	Incident Air Kerma
IPEM	Institute of Physics and Engineering in Medicine
MASH	Male Adult Phantom
MRT	Minimum Response Time
N.A	Not Available
OP	Optimization Phase
PA	Posterior-Anterior
S Value	Sensitivity Value
SF	Screen-Film
SNR	Signal-Noise Ratio
SPSS	Statistical Package for Social Sciences
UNSCEAR	United Nations Scientific Committee on the Effects Of Atomic Radiation

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Radiation dose arising from medical diagnosis is currently reputed as an important tool for diagnosis and treatment. The overarching benefits to patients from properly conducted procedures have fostered the widespread practice of radiology resulting in exposures from medical radiation being an essential part of the total population radiation exposure (Agard, 1997). The levels of radiation dose to the patient undergoing diagnostic examinations with x-rays are determined by the quality of images required and the extent of investigation necessary to meet the clinical objectives. In practice, several factors relating to both the imaging equipment and the procedures have an influence on the imaging process. Thus, effort must be carried out to optimize factors that influence radiation dose and image quality consistent with the concept of ALARA (As Low as Reasonably Achievable).

The need to optimize radiation protection of patients without compromising on diagnostic image quality is enshrined in the International Commission on Radiation Protection (ICRP Report 60). This philosophy of the clinical benefit of the imaging procedure must outweigh the associated radiation risk, thus justifying the practice (UNSCEAR, 2008). In digital systems, dose reduction and optimisation are different compared to that of screen-film radiography. While digital techniques have the potential in reducing patient doses, they can also significantly provide the means of increasing them due to the fact that digital system have wider exposure latitude, greater

dynamic range and post processing abilities (Vano et al., 2007). Thus, the importance and awareness for the need to manage radiation dose as an overexposure can occur without an adverse impact on image quality. Optimization is a balancing act between image quality and radiation dose and does not imply minimizing patient dose while maximizing image quality. Rather, the radiologists are required to decide the image quality level that is necessary for the clinical diagnosis to be made and then minimizing radiation dose without compromising the quality of the image (Ng, 2012). Radiological examinations that utilized x-ray is reputed to be associated with induced malignancy risk resulting from exposure to radiation and deterministic effects if the radiation dose is over the threshold. As such patient radiation doses should be kept as low as reasonably achievable in consistent with the ALARA concept. An appropriate balance between patient radiation dose and image quality can minimized stochastic risks as well as preventing deterministic effects, consistent with the International Commission on Radiological Protection (ICRP) guideline.

1.2 PROBLEM STATEMENT

Digital x-ray imaging is a technology that is rapidly advancing and will soon affect the population at large. If steps are not taken pertaining to issues in radiation protection, medical exposure to patients will significantly increase without concurrently benefiting the patient. While digital techniques have the ability in reducing patient doses they also can provide the means to significantly increase them (ICRP 93 Editorial). Digital imaging can bring about benefits but mandates modifications in the ways of working. Digital x-ray imaging entails issues pertaining to productivity and cost, acquirement of new skills, radiation doses, issues of image quality and overuse.

Current safety issues with clinical digital radiography include that of technical factors such as the automatic exposure control (AEC) and exposure (sensitivity) index. The inherent wide exposure dynamic range of such systems may be disadvantaged if the AEC is faulty or as a result of output calibration drift, hence increase or decrease radiation dose may not be recognized readily. The wide exposure dynamic range could also potentially result in the initial set up for the system not to be optimized. Further, digital radiography systems may differ in x-ray energy responses to image receptor systems. Therefore, the generator's AEC compensation characteristics should be adjusted for different image receptor systems. For existing systems which have been upgraded to CR or DR, the existing AEC compensation characteristics will need reprogramming.

Each image acquired via digital imaging should ideally have a related number to specify the exposure level to the detector. Currently all digital systems have an exposure (sensitivity) index which is associated to the detector exposure. Once digital radiography systems are in use, applied exposure factors constancy should be routinely monitored. Current clinical digital radiography safety human issues such as inapt exposure, number of exposures increased, collimation inadequacy and image quality that is not compatible with imaging tasks must be addressed in order to optimize dose and image quality.

With digital systems, an overexposure can result without adversely impacting image quality. Overexposure may not be recognizable by the radiographer or radiologist. In conventional radiography, over exposure results in a “black” film and exposure inadequacy produces a “white” film, both with contrast reduction. In digital systems, image brightness can be adjusted by post processing, independent of exposure level. A survey of 450 technologists by the American Society of Radiologic

Technologists (ASRT) disclosed that 50% of the respondents utilized electronic cropping after the exposure (Morrison et al., 2011). Poor collimation resulted in large part of the body to be irradiated which is not seen on the digitally cropped image.

1.3 PURPOSE OF THE STUDY

To assess the current practices for common radiographic examinations (chest, abdomen and lumbar sacral spine) using CR and DR and to optimize image quality and radiation dose for the above radiographic examinations.

1.4 RESEARCH OBJECTIVES

1.4.1 General Objective

The general objective of this research is to investigate causes for higher patient dose which have no additional benefit for the clinical purpose intended.

1.4.2 Specific Objectives

The following specific objectives guided this study:

1. To assess the current technical parameters utilized for PA chest, AP abdomen and AP lumbar sacral spine in HOSHAS and HTAA for the pre optimization study.
2. To ascertain other technical factors (focus to image receptor distance (FFD), additional filtration and collimation) that can influence dose optimization and image quality.
3. To compare the difference in image quality and ESD in pre and post optimization.

1.5 RESEARCH QUESTIONS

Six research questions are ascertained to be explored in this research.

The questions for exploration are as follows:

1. What are the current technical parameters utilized for PA chest, AP abdomen and AP lumbar sacral spine radiography in HOSHA and HTAA for the pre optimization study?
2. Is there any significant difference between the entrance surface dose (ESD) received by a reference group of patients for PA chest using DR in HOSHAS and CR in HTAA for the pre optimization study?
3. Is there any significant difference between the image quality produced by a reference group of patients for PA chest using DR in HOSHAS and CR in HTAA for the pre optimization study?
4. Is there any significant difference between the ESD received by a reference group of patients for PA chest, AP abdomen and AP and lateral lumbar sacral spine radiography for the pre optimization phase and post optimization phase in HOSHAS?
5. Is there any significant difference between the image quality produced by a reference group of patients for PA chest, AP abdomen and AP and lateral lumbar sacral spine radiography for the pre optimization phase and post optimization phase in HOSHAS?
6. What are the other technical factors (focus to image receptor distance (FFD), additional filtration, and collimation) that can influence dose optimization and image quality?

1.6 RESEARCH HYPOTHESES

H_{01}: There is no significant difference between the image quality produced by a reference group of patients for PA chest using DR in HOSHAS and CR in HTAA for the pre optimization study.

H_{02}: There is no significant difference between the entrance surface dose (ESD) received by a reference group of patients for PA chest using DR in HOSHAS and CR in HTAA for the pre optimization study.

H_{03}: There is no significant difference between the image quality produced by a reference group of patients for common radiographic procedures for the pre optimization phase and post optimization phase in HOSHAS.

H_{03A}: There is no significant difference between the image quality produced by a reference group of patients for PA chest radiography for the pre optimization phase and post optimization phase in HOSHAS.

H_{03B}: There is no significant difference between the image quality produced by a reference group of patients for AP abdomen radiography for the pre optimization phase and post optimization phase in HOSHAS.

H_{03C}: There is no significant difference between the image quality produced by a reference group of patients for AP lumbar sacral spine radiography for the pre optimization phase and post optimization phase in HOSHAS.

H_{04}: There is no significant difference between the ESD received by a reference group of patients for common radiographic procedures for the pre optimization study and post optimization study in HOSHAS.

H_{04A}: There is no significant difference between the ESD received by a reference group of patients for PA chest radiography for pre optimization phase and post optimization phase in HOSHAS.

H_{04B}: There is no significant difference between the ESD received by a reference group of patients for AP abdomen radiography for pre optimization phase and post optimization phase in HOSHAS.

H_{04C}: There is no significant difference between the ESD received by a reference group of patients for AP lumbar sacral spine radiography for pre optimization phase and post optimization phase in HOSHAS.

H_{04D}: There is no significant difference between the ESD received by a reference group of patients for lateral lumbar sacral spine radiography for pre optimization phase and post optimization phase in HOSHAS.

1.7 SIGNIFICANCE OF THE STUDY

Research in this subject will aid in reducing radiation dose to the patient while still maintaining the diagnostic quality of the images produced consistent with international standards. This in the long run will benefit the patients by reducing the deterministic effects of radiation and to the population at large. The results from this research could augment the awareness and knowledge regarding the impact on radiation dose and image quality to that of the radiographer's practice. Thus, this study will help paved the way for radiographers in improving their ethical and professional practices in fulfilling their obligation in reducing dose and maintaining diagnostic quality of the images produced.

1.8 LIMITATIONS OF THE STUDY

The following may limit the study:

Firstly, due to time constrain, a minimum required sample size was employed in this study and therefore cannot be generalized to the population at large.

Secondly, the results may not be representative of the clinical scenario as the sample size do not include patients with pathological conditions and those patients outside the age and weight range.

Thirdly, the findings were correct at the time of data collection as practices do vary from radiographer to radiographer. Further, patient demographics (age and weight) do change over time.

Lastly, the assessment of image quality even though employed a score sheet can introduce an element of bias as it was based of the visual perceptibility and preference of the radiologists employed.