Effectiveness of Post National Dose Survey (NADs1) Towards Dose Compliance Level

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Abstract. The increasing number of CT procedures owing to advanced CT technology requires careful monitoring by the personnel involved to ensure appropriate examinations and optimized procedures. For that reason, CT optimization is a crucial factor that could help to compensate for radiation dose and image quality. In current practice, optimization in CT is a complex procedure due to a wide range of acquisition parameters in imaging protocols. Diagnostic Reference Levels (DRLs) have been defined by the International Commission on Radiation Protection (ICRP) as a form of investigating the level of patient dose for a specified procedure used in medical imaging to indicate whether, in routine conditions, the patient dose is unusually high or low for that procedure. Hence, the Ministry of Health (MOH) has established a national DRL through a dose survey conducted from 2007 to 2009, and the project is called as NADs1. However, the study does not cover the effectiveness of image quality; in contrast, the current research focuses on both dose exposure and image quality to determine the level of effectiveness of the developed NADs1 data. This study involves several levels, including the acquisition of patient exposure data, image quality assessment, and effective dose measurement. Determination of acquisition of patient exposure data is based on the indicator of QAP CT Brain developed by the MOH, i.e., the total number of adult CT brain examinations for which the DLP value shall not exceed 10\% of the national DRL values, 1050 mGy.cm. The outcome of this study can be used as a measure to optimize patients’ radiation exposures and can be a guide for implementing improvement measures. The results of this study allow radiology personnel to understand the concepts and mechanisms associated with managing patient radiation exposures. The outcome also provides the level of effectiveness of the developed QAP, which was implemented by the MOH and subsequently became a benchmark for improving the quality of healthcare services. Therefore, it is clear that this study has shown an impact on the level of optimization from the radiation exposure study, the NADs2 that is being implemented.
1. Introduction
Computed Tomography (CT), also known as computerized tomography imaging or as a computerized axial tomography (CAT) scan, is an imaging modality that integrates traditional X-ray radiography with computer technology in order to generate 3-D images of the body. The role of CT in modern medicine is well established as a means of diagnosis and also as an essential precursor to radiation therapy treatment. The clinical relevance of the technology and the recent rapid technological developments have brought about extensive increases in the use of this diagnostic tool, generally.

In Malaysia, 11% of diagnostic radiological procedures involve CT, and it has been established that these procedures contribute approximately 67% of the collective effective radiation dose due to medical X-ray examinations [1], [2]. Despite its benefits, the radiation exposure from CT was reported higher compared to other imaging modalities. The complexity of this technology continues to increase, as does its potential to deliver substantial doses to patients [3]–[5].

The actual dose to a specific anatomical location is generally determined by the values selected by the operator for the protocol factors and the size of the patient. In principle, the dose can be reduced by setting the kV, mA and time to lower values and increasing the pitch [6]. The increasing complexity of scanner operation and application requires careful monitoring by the personnel involved to ensure that appropriate examination conditions exist and that procedures are optimized for diagnostic quality and patient dose. Adjustment of the exposure factors is one way to reduce radiation dose, but altering the tube potential may cause the image quality [7]. Hence, this metric should be applied cautiously. Image noise is a major factor in determining dose metrics to the patient, which makes an image with relatively low detail or is blurry [8].

To compensate for the radiation exposure and the quality of the resulting image, a radiation safety objective has to be set to reach the level of optimization of the patient. The objective set is to ensure that the images produced are of diagnostic quality with the least possible exposure to the patient. Consequently, the need for Quality Assurance (QA) for the optimal clinical information at acceptable radiation dose levels is vital [9]. Providing the best possible diagnostic information while the dose that the patient receives is kept to a minimum—the ALARA principle (As Low As Reasonably Achievable) is the basic aim of QA program—optimization of radiological practice.

In today’s modern medicine, a large number of different radiological diagnostic procedures are performed in which patients sometimes receive a significant dose of radiation where the costs of radiological services regarding the equipment and resources needed are high and rising [10]. Given that the poor quality of radiological diagnostic images, which, as a result, often has a repetition of radiographs, is the major cause of unnecessary patient exposure, the main component of the QA program is evaluation of image quality and identifying the cause of poor-quality images and the determination of doses that patients receive in particular diagnostic procedures—a step toward establishment of dose reference levels (DRLs) [11], [12].

Therefore, a study to assess the level of effectiveness of the developed QAP in CT brain examinations needs to be conducted to ensure that the indicator reaches the level of optimization of patient radiation exposure in the same way to produce appropriate image quality. Steps are conducted by evaluating the effectiveness of the post-national dose survey (NADs1) to determine the level of optimization of adult plain CT Brain examination. The outcomes from this study are used to guide if the MOH made some improvement on the implementation of QAP along with the managing process that allows the monitoring and reduction of dose to the patient.

2. Materials and Methods
This study retrospectively evaluated the value of the image parameters, namely Single to Noise Ratio (SNR), for the occipital and frontal sections of the CT brain images. The complete CT protocol information and exposure parameters used to carry out this retrospective study are given in Table 1.

The study was approved by the Hospital’s Ethical Committee as it involved the patient’s personal details. Patient’s data and ID information were obtained from Picture Archiving Computer Systems (PACS).
Data consisting of CT parameters and dose information were extracted from the Digital Imaging and Communication in Medicine (DICOM) header and collected for analyzation purposes. CT Brain procedure with exposure below NADs1 level, 1050 mGy.cm was selected. The next step was to determine the ROI of the occipital side and the frontal region to get the mean, SD, and SNR in order to assess the effectiveness of NADs1. All the CT exposure parameters used were expressed on the protocol, as shown in Table 1 for an adult CT Brain involved in retrospective study. The data recorded were presented in Table 2 below. Both SNR data were determined at the radiation exposure level below the specified DRL reference level, NADS1, which is set at 1050 mGy.cm or NADs1.

### Table 1: Configuration of protocols set for this study.

| Parameters               | Standard Protocols |
|--------------------------|--------------------|
| Tube Potential (kV)      | 120                |
| Tube Current (mAs)       | 349                |
| Nominal beam width (mm)  | 32 x 0.625mm       |
| Table feed (mm)          | 26.9               |
| Pitch factor             | 0.345              |
| Slice thickness (mm)     | 143-159            |

3. Results and Discussion

The calculation of SNR and ROI were grouped according to effective diameters and, in total, as stated in Table 1. CT Brain (Frontal) indicates the maximum SNR value is 6.917 (patient ID 45286), while the minimum SNR value is 3.899 (patient ID 5529). One patient produces consistent minimum values on the Frontal and Occipital sections. This shows that the highest SNR readings are at 6.917 (Frontal) and 7.415 (Occipital). The lowest SNR reading was 3.719 for both sections of the CT Brain. Observations also found that the mean value for the frontal region was 31.756 (patient ID 45313). However, due to the relatively high SD (noise) level of over 40% compared to the procedure that produces high SNR readings (ID 45286), it contributes to the reduction of SNR values.

Table 2 also shows that there are 2 CTDIvol values of 55.29 mGy and 55.06 mGy. The majority of CTDIvol generated is at 55.29 mGy, while the DLP data generated was relatively uniform, with the lowest readings being 945.2 mGy.cm and the highest being 1040.3 mGy.cm. Referring to the case of ID45286 patient, the SNR value showed the highest reading as 6.917 at the DLP value of 945.2 mGy.cm, which is the minimum DLP value; the highest SNR reading was 7.415 with DLP 1040 mGy.cm being the maximum DLP value. This information can serve as a benchmark for the user to determine the quality of each procedure performed. All of these data are in the form of box plots, as shown in Figure 1.

In principle, each procedure aims at the objective of producing optimum quality with minimum/least possible exposure [13], [14]. In other words, each of these procedures can achieve the maximum SNR to produce the best image quality while receiving radiation exposure at the lowest possible DLP. It is difficult to achieve the objectives of the target due to the various factors involved, such as procedures, equipment and techniques. This can be illustrated by the results of the analysis of the data described in Figure 1. There are cases of procedures that produce the highest Mean, but due to high SD values, they contribute to lower SNR values. Concomitantly, for the assumption of radiation value, a larger DLP would produce a higher SNR. However, the opposite is the case where the SNR value is derived from the procedure with the least DLP. Therefore, the factors that contribute to this optimization need to be reviewed.
This study is at the early stage in determining the effectiveness of radiation exposure optimization in NADS1-based CT Brain procedures. Therefore, in order to make the assumptions more accurate, a follow-up study should be conducted based on the previously described selection test method. For example, if a procedure produces low SNR values up to Q1, then physical testing should be performed. Similarly, for procedures that produce high radiation exposure, they must be validated in terms of effective radiation exposure levels to confirm the patient’s safety level.

Table 2. Image quality based on quantitative measurement for selected patients

| Patient ID | Sex (M/F) | Region of Interest (ROI) | Patient Exposure* |
|------------|-----------|--------------------------|-------------------|
|            |           | Frontal                  | Occipital         | DLP, mGy.cm | CTDIvol mGy |
|            |           | MEAN   | SD    | SNR      | MEAN  | SD    | SNR      |              |              |
| 45337      | M         | 27.410 | 5.944 | 4.611    | 29.904 | 6.617 | 4.519    | 1033.7       | 55.29        |
| 45336      | F         | 27.586 | 5.222 | 5.285    | 37.359 | 5.720 | 6.531    | 1000.4       | 55.29        |
| 45335      | F         | 27.090 | 4.782 | 5.665    | 38.235 | 5.157 | 7.415    | 1040.3       | 55.06        |
| 45334      | M         | 30.825 | 5.023 | 6.137    | 31.991 | 6.540 | 4.892    | 983.9        | 55.29        |
| 45314      | F         | 31.756 | 5.731 | 5.541    | 31.991 | 6.540 | 4.892    | 983.9        | 55.29        |
| 45313      | F         | 28.398 | 5.222 | 5.438    | 40.301 | 6.876 | 5.861    | 1040.3       | 55.06        |
| 45286      | F         | 26.871 | 3.885 | 6.917    | 34.962 | 6.820 | 5.126    | 945.2        | 55.29        |
| 45285      | M         | 28.758 | 5.9    | 4.874    | 36.845 | 5.771 | 6.395    | 1033.7       | 55.29        |
| 45289      | M         | 24.635 | 6.319 | 3.899    | 32.239 | 8.669 | 3.719    | 1011.6       | 55.29        |
| 45261      | M         | 30.301 | 5.582 | 5.428    | 31.881 | 5.230 | 6.096    | 1011.6       | 55.29        |

Figure 1. The boxplot data shows SNR value for ROI of occipital and frontal in CT Brain examination
4. Conclusion
It can be concluded that the form of the SNR indicator can guide the level of optimization for the CT procedure (CT Brain). This study has also shown that DRLs from NADs can prove effective towards dose compliance levels. Based on the study, the SNR reference benchmark can indicate the intervention condition in order to be more practical for the optimization of radiation protection on patients. In an effort to reduce radiation dose, the effect of physical image quality and the ability to carry out the clinical imaging task must be considered.

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