Assessment of radiation effective dose from lung cancer screening pilot project in Institut Kanser Negara: A preliminary finding

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Abstract. The aim of this study is to evaluate effective dose received by participants from Lung Cancer Screening program in Institut Kanser Negara (IKN), Putrajaya. This retrospective study was performed between April 2016 – December 2016 where all scanning acquisition protocols and dose information from forty (40) participants were recorded and investigated. The screening process involves two types of imaging technique, the Dual Energy Subtraction (DES) Chest X-ray and Low-Dose Computed Tomography (LDCT) imaging technique. Participant’s effective dose (ED) from DES and MSCT were analysed by using PCXMC (Version 2.0, Finland) and CT-EXPO (Version 2.3, Germany) software, respectively. It was observed that the mean (±SD) value for DES (at 60 kV), DES (at 120 kV) and MSCT examinations were 0.006 ± 0.005 mSv, 0.018 ± 0.005 mSv and 1.558 ± 0.129 mSv, respectively. In a whole, the total cumulative ED values for participants were ranged from 1.376 mSv to 1.986 mSv. It was summarized that both optimized techniques were useful for screening needs and the ED value from this study were lower when compared to other established reference.

1. Introduction
Lung cancer is one of the most common cause for cancer death worldwide. According to the 2014 World Health Organization (WHO) report, lung cancer accounted for 19.1 deaths per 100,000 population in Malaysia or 4,088 deaths per year (3.22% of all deaths), the second cause of cancer death in the country after breast cancer and the eight most common cause of death from all causes [1]. This alarming trend, has led Ministry of Health (MOH) Malaysia to initiate a lung cancer screening project, aim to pick up lung cancer at an early stage, hence improving survival rate.

Conventional lung cancer screening program usually involves two different methods, a chest X-ray radiography (CXR) and analysis of sputum cytology. However, both techniques have poor sensitivity which led to false-negative diagnosis and to overcome this drawback, most institutes using a High-Resolution CT (HRCT) thorax technique for the screening programme, with its primary objective is to
improve lung nodule detection [2–4]. Although, the true-positive rate improves for detecting lung nodule, radiation dose from CT are of concerned. Therefore, the technique was improved by combining Low-Dose CT (LDCT) and Dual-Energy Subtraction (DES) Chest X-ray technique to ensure that detection rate might improve [5].

The main advantage of using LDCT in screening asymptomatic patients is the balance of producing diagnostic quality images with the most applicable low dose exposure [6]. Several studies previously have reported on optimization technique during screening using LDCT and shows the dose can be reduced up to 30% if correct acquisition parameters were used [7]. To the best of our knowledge, no studies had comprehensively assessed patient radiation dose from lung cancer screening using both LDCT and DES imaging technique. Therefore, this study aims to provide preliminary data on the dose received by the subjects specifically effective dose value from Lung Cancer Screening Programme in Malaysia.

2. Methodology
This study was approved by the institutional research ethics committee with approval number NMRR-16-128-28790. A small preliminary checked was done by the clinical staff before the screening process. 40 subjects were enrolled in this study as they comply with the following criteria; age above 50 years old, smoking history for more than 30 packs per year and weight between 50 to 90 kg. After subjects were ready, the radiographers will execute the scanning process as in standard examination protocols. The screening process involves 2 type of examination; namely 3D distribution of CT examination and 2D projection of DES imaging technique.

2.1. Effective dose measurements
The dosimetry principle was based on the established guidelines where the effective dose, $E$, is total of the product of the equivalent dose with the weighting factor of all tissues and organs of the human body [8]. The equation for effective dose is:

$$E = \sum w_T H_T$$

where $w_T$ is the weighting factor and $H_T$ is equivalent dose. Unit for effective dose is J/kg or Sievert (Sv).

In this study, Monte Carlo technique was used for simulating the radiation dose received by subjects. Effective dose and organ dose from DES and LDCT techniques were estimated using PCXMC (Ver 2.0, STUK) and CT-EXPO (Ver 2.3.1, Germany), respectively. PCXMC, the mathematical stylized phantom is used to represent human body features adapting 2D X-ray projection. This model includes anatomic shapes in order to get the real structure, human various ages, weight and height [5]. Similar as PCXMC, CT-EXPO also using a stylized phantom which is based on the characteristics of the MIRD-5 phantom. Several parameters such as air Kerma, tube output, entrance surface air Kerma (ESAK) and dose area product were required before running the software. Noting that, the Automated Tube Current Modulation (ATCM) was disable and tube current was fix at 25 mAs. The scanning acquisition parameter used for DES and LDCT were shown in Table 1 and Table 2, respectively. Figure 1 shows the reference phantom use in CT-EXPO which known as ADAM and EVA.

| Parameter                  | DES protocols                                      |
|----------------------------|----------------------------------------------------|
| Tube potential (kV)        | Dual energy: 60 and 120 kV                         |
| Tube current (mAs)         | 6.0-7.0 (60 kV) and 1.0-2.5 (120 kV)              |
Table 2. Scanning parameters of LDCT for lung cancer screening program in IKN.

| Parameter       | Tube potential (kV) | Tube current (mAs) | Nominal beam width (mm) | Pitch factor | Slice thickness |
|-----------------|---------------------|--------------------|-------------------------|--------------|----------------|
| LDCT protocols  | 120                 | 25 (ATCM disabled) | 64 X 0.5                | 0.9          | 1.0            |

Figure 1. The reference phantom used in CT-EXPO for estimating effective dose and organ equivalent dose.

3. Results and Discussion
The characteristics of the 40 subjects (all males) are presented in Table 3. The age of subjects across all studies were 50 to 70 years old; mean values for weight, height and BMI were 72.5 kg (where Confidence Interval (CI): 67.6, 77.6), 1.67 m (CI: 1.64, 1.68) and 26.1 kg.m$^{-2}$ (CI: 24.4, 27.8), respectively. The mean packs of cigarette smoked by patients are 40.7 packs per year.

Table 3. Characteristics of the subjects involves in the screening process

| Statistics                        | Mean ± SD | Min - Max |
|-----------------------------------|-----------|-----------|
| Age (y/o)                         | 52.5 ± 10.3 | 50 - 70  |
| Weight (kg)                       | 72.5 ± 14.5 | 50 - 90  |
| Height (m)                        | 1.67 ± 0.06 | 1.57 – 1.89 |
| BMI (kg.m$^{-2}$)                 | 26.1 ± 4.7 | 18.6 ± 4.3 |
| Packs of cigarette per year       | 40.7 ± 14.5 | 15 - 80  |

3.1. Acquisition parameters and radiation dose
Table 4 provides a summary of acquisition parameter as well as dose information for DES imaging technique. The mean values of the beam size for all DES examinations were 39.9 cm x 38.7 cm, performed at various tube currents ranged from 2.9 to 16.9 mAs and 0.9 to 2.7 mAs for potential energy at 60 and 120 kVp, respectively. The mean values of exposure time were ranged from 6.3 mAs to 20.4
mAs depending on the Automatic Exposure Control (AEC) input from the scanners. In DES, there is no significant different between the mean values of Dose-Area Product (DAP) obtained from both energy potential, where at 60 kV the mean value of DAP was 0.69 mGy.cm\(^2\) (CI: 0.60, 0.80) and at 120 kV the mean value of DAP was 0.72 mGy.cm\(^2\) (CI: 0.64, 0.80).

| Parameters                          | Min – Max (Mean ± SD) | 95% Confidence Interval (CI) | Lower | Upper |
|-------------------------------------|------------------------|------------------------------|-------|-------|
| **at 60 kV**                         |                        |                              |       |       |
| Tube current (mAs)                  | 2.9 – 16.9 (5.1 ± 2.4) | 4.2                          | 6.0   |       |
| Exposure time (ms)                  | 12.0 – 68.0 (20.4 ± 10.0) | 16.9                        | 23.9  |       |
| Dose area product (DAP)             | 0.30 – 2.50 (0.70 ± 0.30) | 0.60                        | 0.80  |       |
| **at 120 kV**                        |                        |                              |       |       |
| Tube current (mAs)                  | 0.9 – 2.7 (1.2 ± 0.3)  | 1.1                          | 1.3   |       |
| Exposure time (ms)                  | 5.0 – 14.0 (6.3 ± 1.7)  | 5.7                          | 6.9   |       |
| Dose area product (DAP)             | 0.40 – 1.70 (0.72 ± 0.23) | 0.64                        | 0.80  |       |

Table 4. Scanning acquisition parameters and dose output for DES imaging technique.

Table 5 tabulates data for acquisition parameters and dose information for LDCT imaging technique. The tube potential and tube current were standardized respectively at 120 kV and 25 mAs while for scan length, depending on the subject’s habitus, ranged from 24.0 cm to 41.0 cm. The mean values for CTDI\(_{vol}\) were 3.03 ± 0.05 mGy while for DLP were 111.3 ± 9.3 mGy.cm.

| Parameter   | Min – Max (Mean ± SD) | 95% Confidence Interval (CI) | Lower | Upper |
|-------------|------------------------|------------------------------|-------|-------|
| Scan length | 24.0 – 41.0 (32.5 ± 3.1) | 31.5                        | 33.5  |       |
| CTDI\(_{vol}\) | 3.00 – 3.10 (3.03 ± 0.05) | 3.02                        | 3.04  |       |
| DLP        | 96.4 – 140.0 (111.3 ± 9.3) | 108.1                      | 114.5 |       |

Table 5. Scanning acquisition parameters and dose output for LDCT imaging technique.

3.2. Subject’s effective dose
The effective dose from each acquisition was calculated by using the formalism implemented in PCXMC and CT-EXPO for DES and LDCT, respectively. As indicated in Table 6, the results revealed that mean values of ED from DES (60kV), DES (120kV) and LDCT were 0.006±0.003, 0.018±0.005 mSv and 1.56±0.13 mSv, respectively. It was estimated that the ED received by the subjects were ranged from 1.38 to 1.99 mSv.

Our study finds that there is a significant difference of ED between LDCT and routine CT thorax. Therefore, tube current might be one variable that has significant changes in radiation doses. Although, ED for LDCT was lower, the DES imaging still allows much better reduction of doses and have significant impact on diagnosis based on our observation. Since this is a preliminary study, which to determine the ED, the sensitivity level of both modalities is plan as our next future studies.
Table 6. Scanning acquisition parameters and dose output for DES imaging technique.

| Imaging technique | Min – Max (Mean ± SD) (unit in mSv) | 95% Confidence Interval |
|-------------------|-------------------------------------|-------------------------|
|                   |                                     | Lower | Upper |
| LDCT              | 1.34 – 1.97 (1.56 ± 0.13)           | 1.51  | 1.59  |
| 60 kVp            | 0.003 – 0.022 (0.006 ± 0.003)       | 0.005 | 0.007 |
| 120 kVp           | 0.011 – 0.042 (0.018 ± 0.005)       | 0.016 | 0.020 |
| Total             | 1.38 – 1.99 (1.58 ± 0.13)           | 1.54  | 1.62  |

4. Conclusion

In this study, we present the radiation doses specifically effective dose value from two different imaging techniques, DES and LDCT, which utilised in Lung Cancer Screening program. As conclusion, our results show that the estimated effective dose for DES technique was comparable, whilst for LDCT, was reduced by a factor of 4 to 6 as compared to other established studies. The ED ranges occurred due to variation in subject’s body habitus and variables of scanning parameters which influenced by the exposure output.

References

[1] Azizah Ab M N. 2017 Malaysian National Cancer Registry Report Ministry of Health Malaysia
[2] Linnane B, Robinson P, Ranganathan S, Stick S and Murray C 2008 Role of high-resolution computed tomography in the detection of early cystic fibrosis lung disease. Paediatr. Respir. Rev. 9 168-74
[3] Kuhlman J E, Collins J, Brooks G N, Yandow D R and Broderick L S 2006 Dual-energy subtraction chest radiography: what to look for beyond calcified nodules Radiographics 26 79–92
[4] Podberesky D J, Angel E, Yoshizumi T T, Toncheva G, Salisbury S R, Brody A S, Alsip C, Barelli A, Egelhoff J C, Anderson-Evans C, Nguyen G B, Dow D and Frush D P 2013 Comparison of radiation dose estimates and scan performance in pediatric high-resolution thoracic CT for volumetric 320-detector row, helical 64-detector row, and noncontiguous axial scan acquisitions. Acad. Radiol. 20 1152–61
[5] Manji F, Wang J, Norman G, Wang Z and Koff D 2016 Comparison of dual energy subtraction chest radiography and traditional chest X-rays in the detection of pulmonary nodules Quant. Imaging Med. Surg. 6 1–5
[6] Karim M K A, Hashim S, Bakar K A, Muhammad H, Sabarudin A, Ang W C and Bahruddin N A 2016 Establishment of multi-slice computed tomography (MSCT) reference level in Johor, Malaysia J. Phys. Conf. Ser. 694 012033
[7] Karim M K A, Hashim S, Bradley D A, Bakar K A, Haron M R and Kayun Z 2016 Radiation doses from computed tomography practice in Johor Bahru, Malaysia Radiat. Phys. Chem. 121 69–74
[8] International Atomic Energy Agency 2007 Dosimetry in Diagnostic Radiology : An International Code of Practice

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