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RESEARCH ARTICLE

RADIATION DOSE AND ASSOCIATED EXPOSURE PARAMETERS IN SELECTED MDCT SCANNERS IN MULTIPHASE SCAN OF ABDOMEN- PELVIC REGION: A CLINICAL STUDY.

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Abstract

We sought to estimate the radiation dose and associated exposure parameters in the multiphase abdomen - pelvic scan of Multidetector Computed Tomography (MDCT) studies in clinical practice.

This was a retrospective cross sectional study describing radiation dose associated with main exposure parameters in diagnostic multiphase abdomen - pelvic scans performed on 152 consecutive patients by two different sixteen (16) slice CT scanners. Patient information, exposure parameters of CTDI_(volume), DLP, kVp, mAs and pitch were recorded for every phases of abdomen- pelvic study from dose report of MDCT scanners.

Patient age range from 18 to 87 years. Overall CTDI_(volume) median was 63.8 (±10.4)mGy for multiphase abdominal-pelvic scan with scanner A while it was 35.4 (±15.6)mGy for scanner B. Effective dose for patients in multiphase abdomen - pelvic CT scan range from 8.2 mSv to 58 mSv. Median effective dose for patients, who underwent multiphase abdomen- pelvic scan with scanner A and B were 38.5 (± 8.2) mSv and 21.3 (± 8.6) mSv respectively. Median value of exposure parameters of mAs, kVp and pitch were 150 (±29.7), 130 (±15.3) and 1.3 (±0.1) respectively in scanner A. In scanner B; they were 60 (±14.5), 120(±0)and 1(±0). The median effective dose for patients between multiphase abdomen-pelvic scan of both MDCT, a significant difference ($P<0.05$) was observed. Multiphase abdomen – pelvic scan of clinical study shows significant variation of effective dose with reference level of phantom studies (8-14 mSv) and it is highly depend on type of vendors.

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Introduction:-

Computed tomography (CT) is useful for diagnostic purposes of abdominal and pelvic diseases and is one of the most important radiological examinations undertaken worldwide [1], [2]. Approximately 3 million scans were performed annually in the United States in 1980, and by 2008 that number had grown to 67 million[3]. CT allows

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physicians to diagnose the injuries and diseases which are related with abdominal and pelvic regions more quickly, safely and accurately than alternative more invasive or less sensitive imaging techniques[2],[3]. In general a CT examination of the abdomen and pelvis includes transaxial images from above or level of the dome of the diaphragm to the just below the ischial tuberosities [4]. In certain cases, it may be appropriate to limit the area exposed and focus only on the area or organs of concern in order to limit the radiation dose. This is especially advised in patients with multiple CT studies and follow-up examinations [4],[5].

Optimizing abdominal CT examination technique requires the supervising physician to develop appropriate CT abdominal protocols based on careful review of the patient history and clinical indications, as well as all relevant imaging studies when available [6],[7]. This optimization process may include determining whether CT examinations of the abdomen, pelvis, or both are necessary. Normally abdominal or pelvic CT examinations may be performed with multiple acquisitions, which include non-contrast, contrast injection of arterial and venous phases. Further according to the pathological condition delay phase also will be included [7-9].

Even though the risk to an individual patient may be small, the increasingly large number of people are exposed, coupled with the increasingly high exposure per CT examination, could transform into many cases of cancer resulting directly from the radiation exposure from CT. The Effective dose from CT is much higher than effective dose in conventional radiography; greater use of CT has resulted in a concurrent increase in the medical exposure to ionizing radiation. Studies of occupational exposure to radiation have provided some direct estimates of the risk at lower doses for adults. Undergoing 2 to 3 abdominal CTs over a person's lifetime can increase the possibilities to develop cancer [10-14]. Relatively fewer data describe how much radiation is received through the most common types of CT examinations for abdomen-pelvic area when applied in clinical practice, as most published studies focused on phantom studies.

Previous literature estimates the radiation dose for an abdomen - pelvic CT to be equivalent to 100 to 250 two view chest series (Anterior posterior and lateral) [15-18]. It is impractical to directly measure the radiation dose absorbed by individual patients even when the radiation emitted by a machine is precisely known. Instead, radiation exposure may be quantified using various methods. Modern multidetector CT scanners (MDCTs) provide two dose parameters that both became available by the scanner manufacturers: the Volume CTDI (CTDI_{vol}) measured in mGy, and the dose-length product (DLP) measured in mGy-cm [19], [20]. The total amount of radiation delivered to a standardized phantom is represented by the DLP, which is the product of (CTDI_{vol}) and the scan length. Organ doses in CT should well below the threshold for the induction of deterministic effects. CT examinations should be performed only when a net patient benefit is anticipated. Further, the amount of radiation used should always be kept as low as reasonably achievable (ALARA) [21-23]. According to the phantom studies typical effective dose limit of abdominopelvic examination is 8–14 mSv [24].

Higher numbers of MDCT scanners are observed in government and private hospitals in Srilanka, sixteen slices CT scanner is common trend and have higher numbers among MDCT scanners, based on we planned to investigate patient effective dose during multiphase abdominopelvic scan in MDCT [25].

Materials and Methods:-

Study Design:-

This was a retrospective cross sectional study describing radiation dose associated with main exposure parameters in diagnostic multiphase abdomen - pelvic scans performed on 152 consecutive patients by two different sixteen slice CT scanners between January 5th and October 5th, 2015. Data was collected only from patient who underwent to the multiphase abdomen- pelvic CT examination at one of the hospital in Srilanka. CT data was divided into routine non-contrast phase, contrast triple phase (non- contrast, arterial and venous phases) and multiphase abdomen - pelvic scan (non-contrast, contrast triple and delay phases). Demographic information of patient' age, sex and radiation factors kVp, mAs, pitch, DLP and CTDI_(volume), in non-contrast and contrast phases of arterial, venous and delay were recorded from automatically generated dose report from each scanners after the scan is completed. Each hospital use same generation of MDCT but from different vendors.

Table 1:- Selection of exposure parameters.

MDCTs	Exposure parameters	Phases	Min	Max	Median
		(n)			
A	kVp	317	85	210	130 (± 15.3)
	mAs	317	75	225	150 (± 29.7)
	Pitch	317	0.8	1.5	1.3 (± 0.1)
B	kVp	302	120	120	120
	mAs	302	60	119	60 (± 14.5)
	Pitch	302	1	1	1

Multiphase abdominal scans performed by same radiological technologist and same time it was interpreted by one particular specialized radiologist. Automatic tube current modulation (ATCM) did not apply for all abdomen – Pelvic scans since it compromising image quality.

Calculation of the Effective Dose:-

It is impractical to directly measure the radiation dose received by an individual patient even when the radiation emitted by a MDCT is precisely known. Instead, there are various methods can be used to measure radiation exposure. In our study we used the “effective dose” to quantify the radiation exposure associated with each MDCT multiphase abdomen- pelvic scan; this is one of the most frequently reported measurements. Furthermore, effective dose allows comparison of distribution of radiation dose among individual who referred to the multiphase abdominal – pelvic scan. . The effective dose defines that, the amount of radiation to the exposed organs and each organ’s sensitivity to developing cancer from radiation exposure. Radiation parameter of DLP in MDCTs is combined with the conversion factor K to translate into the effective dose. Abdomen- pelvis region conversion factor (K) is $0.015 \text{ mSv mGy}^{-1} \text{ cm}^{-1}$.

$$\text{Effective Dose} = \text{DLP} \times K (\text{Abdomen-pelvis})$$

Results:-

Demographic Information of Patient:-

Every recorded data is analysed by commercially available Miniab statistical software. Among 152 consecutive patients from both MDCTs, 78 patients were from scanner A while 74 were from scanner B. Mean age of patients from scanner A was $58.94 (\pm 15.1)$ years and it ranged from 18 – 86 years. In scanner B mean age was $55.5 (\pm 15.7)$ years; it ranged from 14 – 87 years. Main reasons for multiphase CT examination were due to suspected liver and renal neoplasm, pancreatitis or hepatitis, suspected renal stones or obstructions.

Comparison of kVp, mAs and Pitch among MDCTs:-

Many parameters influence to radiation dose in MDCTs. Among these factors kVp, mAs and pitch have a significant contribution to radiation dose which may be changed according to the type of the patient and type of the exam protocol in abdomen- pelvic examination.

A total of 619 phases were performed in 153 patients, 51.21% (317/619) phases received from scanner A while 48.79 (302/619) phases were recorded in scanner B. Some patients received two or more delayed phases from both MDCTs according to disease condition or medical consultant referral. Median value of main exposure parameters of mAs, kVp and pitch were 130 (± 15.3), 150 (± 29.7) and 1.3 (± 0.1) respectively in scanner A. For scanner B; they were 120, 60 (± 14.5) and 1 respectively. Specially kVp and pitch factors were not changed during multiphase abdominal- pelvis scan with phases for a patient as well as among the patients in scanner B. Overall kVp, mAs and pitch range from 85, 60 and 1 to 210, 225 and 1.5 respectively in both MDCT scanners in multiphase abdominal- pelvis scan.

Comparison of Median CTDI (volume) in MDCTs:-

Scanner B had lower median CTDI_(volume) value in every phase of multiphase abdomen – pelvis scan than scanner A. Recorded lowest CTDI_(volume) was 26.50 mGy. Scanner B had maximum CTDI_(volume) for Abdomen – pelvis scan in non-contrast phase, was 23.2 mGy while A had 22.4 mGy. There was a significant difference between the mean and median values in routine contrast and multiphase abdomen-pelvis scan of scanner A. this is due to wide adjustment of exposure parameters between scans.

Distribution of Median Effective Dose Received By Patients:-

All phases patient who underwent abdominal–pelvic scan by scanner A received higher median effective dose than patient with scanner B. Minimum effective dose received in patients in non-contrast phase was 2.0 mSv in scanner B, the maximum effective dose was 14.8 mSv in scanner A. The minimum effective dose received by the patient was 6.8mSv and which was from the scanner B. The maximum effective dose received by the patient was 43.4mSv and it has from the scanner A. In multiphase abdomen - pelvic phase maximum effective dose was observed among patients with scanner A, was 58.0 mSv while minimum was observed with scanner B, 8.2mSv. Overall median effective dose for patients among both MDCTs differ from 21.3mSv to 38.5 mSv.

Two tail *t*- sample test performed to check whether any significant differences between the median values of effective dose of patients in every phases, among both MDCTs. It revealed the both scanner median effective dose showed significant difference in any phases ($P>0.05$). Patient received higher amount of effective dose by scanner A than scanner B in every phases of multiphase abdomen- pelvis scan.

Table 2:- Variation of CTDI_(volume); mGy among scanners

	Number of Patients (n)		CTDI _(volume) ; mGy		
			Median (±SD)	IQR	Min-Max
A	78	NC - phase	16.7 (±3.5)	2.4	5.4 - 22.4
		Triple phase	47.6 (±9.1)	7.6	16.8 - 68.4
		Multi-phase	63.8 (±10.4)	9.7	32.8 - 90.8
	74	NC - phase	8.2 (±4.2)	6.3	1.9 - 23.2
		Triple phase	26.2 (±11.3)	18.2	19.4 - 58.0
		Multi-phase	35.4 (±15.6)	24.2	26.5 - 81.1

Table 3:- Variation of Effective Dose; mSv among the scanners

MDCTs	Patients (n)	Phases	Effective Dose; mSv		
			Median (±SD)	IQR	Min-Max
A	78	NC - phase	10 (± 2.5)	2.8	3.4 - 14.8
		Triple phase	29.5 (± 6.4)	7.5	13.5 - 43.4
		Multi-phase	38.5 (± 8.2)	9.5	18.6 - 58.0
B	74	NC - phase	5.25 (± 2.8)	2	2.0 - 18.3
		Triple phase	14.6 (± 6.2)	10.3	6.2 - 40.4
		Multi-phase	21.3 (± 8.6)	9.4	8.2 - 57.3

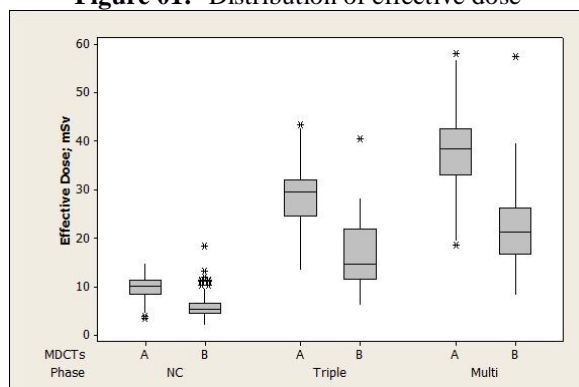
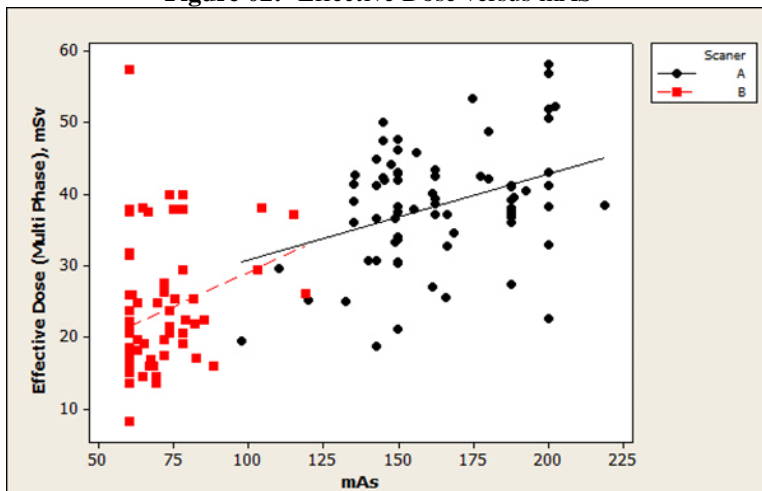
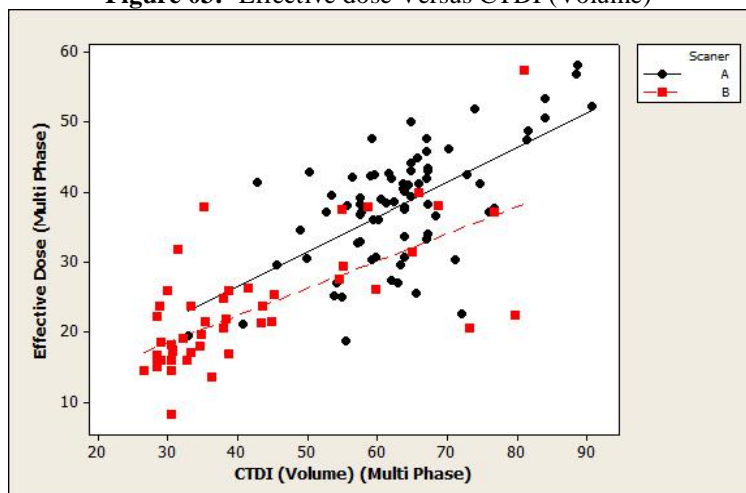
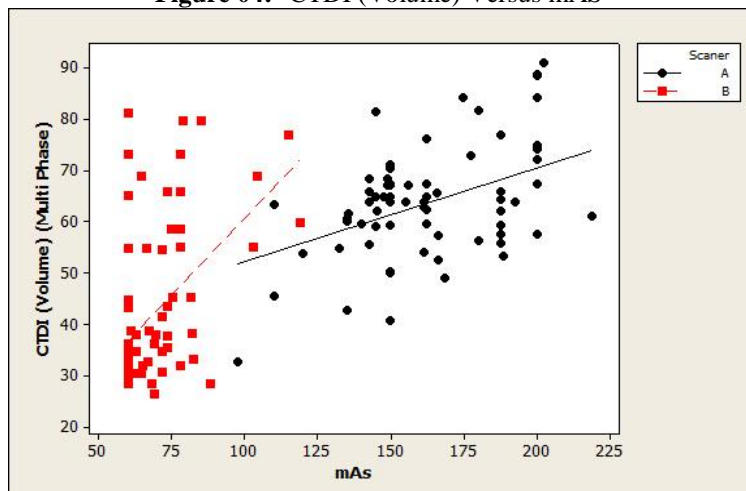
Figure 01:- Distribution of effective dose

Figure 02:- Effective Dose versus mAS**Figure 03:-** Effective dose Versus CTDI (Volume)**Figure 04:-** CTDI (Volume) Versus mAS

Discussion:-

The motivation for this study was the anecdotal observation that large number of multiphase abdomen – pelvis scans performed on the patients. In our study we depicted that higher and more variable calculated effective dose than references level of phantom studies (8-14 mSv).

Our calculated median effective dose for patients from both MDCTs A and B were $38.5 (\pm 8.2)$ mSv and $21.3 (\pm 8.6)$ mSv respectively, it showed significant difference with phantom studies ($P > 0.05$). Thus, this value depends on where and which MDCTs used to scan an individual with the specific technical parameters used to perform that particular scan. While some of these variations may be clinically indicated to accommodate patients of different size or specific to the clinical question that was being addressed, the variation in effective dose was dramatic and of greater magnitude than widely considered acceptable, particularly considering that the patients were already stratified within relatively well-defined clinical groups.

The doses we documented may be higher than typically reported for following the main reasons. First, we estimated radiation doses received by patients in clinical practice, whereas many previous studies have assessed the dose received in idealized settings on phantoms. Study parameters applied in phantoms may differ substantially from those used in actual clinical settings. Second, most prior work described experience in a single type of MDCT study, where the specific instructions for conducting studies may be standardized. We studied patients in clinical practice, who underwent imaging for a range of clinical indications. For example, a common clinical indication for a multiphase abdomen-pelvic CT scan is suspected renal cancer in a patient.

Other researchers also concluded that calculated effective dose showed considerable variation and different compared to phantom studies [1]. As well we observed through our study according to the type of MDCTs patient will receive various amount of effective doses from abdomen-pelvic scan of MDCT. Mainly it depends on the main exposure parameters kVp, mAs and pitch and the type of scanner.

We conducted our study only on sixteen slice multi detector computed tomography while prior researchers' have not mentioned the type of MDCT scanner, they generally quoted as MDCT. Effective dose for abdomen-pelvic region primarily depends on the type of imaging technique that radiological technologists used to obtain consistent acceptable diagnostic CT images and type of MDCTs.

We noticed radiological technological technologist performed two or more delay phase scan on abdomen-pelvic region on some patients. This is one of the reasons for high variation values of $CTDI_{(volume)}$ and calculated effective dose also. Although the retrospective nature of this study did not allow us to investigate the reasons behind the performance of multiphase abdomen- pelvic scan relay with dose limits according to the international guidelines. We suspect that a lack of focus on performing protocols based dose restriction or automatic mA or kVp modulations were not applied by the radiological technologist during the scan procedure.

There is a possibility that CT may cause more adverse effect than its strength in diagnosing the disease conditions with respect to screening of Multiphase abdomen- pelvic scan conducted in asymptomatic persons [25]. In contrast, CT is generally considered to have a very favorable risk to benefit profile among symptomatic patients.

The patients' exposure to radiation through medical imaging needs to be reduced specially in CT, and we believe that three general approaches should be taken. First, CT examination protocols and techniques should be optimized and standardized to limit the radiation associated with individual scans. This would include standardizing protocols across the hospital and among radiological technologists.

Second, Physicians who recommend the CT scan and radiological technologist who perform the scan should reduce the unwanted multiple series of scan within each examination. Every radiological technologist should possess the knowledge or special training regarding to the implementation of the dose reduction strategies according to the MDCTs types, for example, for certain CT study types, dose reduction techniques can reduce the dose by 50% or greater [26] and encouraging participation in accreditation programs such as that offered by international professional associations. Creating specific standards for CT examinations and requiring adoption would lead to a reduction in median and outlier doses, however in practice, these guidelines have not been widely embraced, perhaps because no regulatory component is associated with their use.

The third approach is to reduce exposure according to the evidence based practice. A good record keeping methods according to the standard regulations will improve the knowledge related to the dose reduction. Picture archiving and communication system (PACS) enable the radiologist and radiological technologist to review the previous record related with CT images and to improve their knowledge.

Our study also has several weaknesses. Our cohort was insufficiently small to understand the reasons for the variation of the dose associated with each individual patient, including the radiological technologist's experience, the availability of physicians to check the studies in real time that might lead them to add or subtract additional series, geographic variation, type and specific dose-reduction or dose modulation algorithms available or used. Patients' body mass index (BMI) is the main factor which will determine how much radiation dose they will receive during the CT examination. However in our study we did not measure the BMI of each patient.

Our work highlights the need for large national studies to understand how these factors contribute to variation in radiation dose. Similarly, we did not access the quality of the CT images through specialized image processing software to check whether they have same image quality or not. We predicted that image quality will be the same because same radiological technologists and radiologist have been worked with both MDCTs.

The methods we used to assess radiation dose may be reliable. We presented "effective dose," calculated using the scanner-provided DLP measurement, because this is simple to calculate, straightforward, and reliable and thus can be used as an easy starting point to begin to record patient-level exposure. Although different metrics yielded slightly different estimates and these methods are based on assumptions of patient size that may not be applicable to all patients, this method is highly concordant with other methods of estimating dose [28].

Conclusion:-

A significant difference in median effective dose was observed between the two scanners for patient who underwent multiphase abdomen-pelvic scan. Multiphase abdomen – pelvic scan of clinical study shows significant variation of effective dose with reference level of phantom studies (8-14 mSv) and it is highly depend on type of vendors.

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