Estimation of Cancer Risks Arising from Medical Exposure to Ionizing Radiation of a Population in Southwestern Nigeria.

C.J. Olowookere, Ph.D.[1]; N.N. Jibiri, Ph.D.[2]; T.O. Bello, MBBS[3]; and C. Aborishade, Ph.D.[4]

[1]Department of Physical Sciences, Ajayi Crowther University, Oyo Town, Nigeria.
[2]Radiation and Health Physics Research Laboratory, Department of Physics, University of Ibadan, Ibadan, Nigeria.
[3]Department of Radiology, Ladoke Akintola University of Technology Teaching Hospital, Osogbo, Nigeria.
[4]Department of Physics, Obafemi Awolowo University, Ile Ife, Nigeria.

E-mail: olowokerec@yahoo.com
Telephone: 234 706 481 6962

ABSTRACT

One of the objectives of x-ray examination is the production of high quality images; however, administered radiation doses may be harmful to patients' health. Because of inadequate knowledge of referring physicians and radiologists on the level of patients' exposures during diagnostic medical imaging, especially in the developing countries, many patients are at health risks. This study was therefore designed to estimate the cancer risks resulting from medical diagnostic examinations in Southwestern Nigeria. The results show that the ranges of cancer incidences expected per annum for patients undergoing chest PA examinations for different organs are: lung (227-452), breast (28-207), esophagus (8-26), stomach (28-78), and liver (14-95).

(Keywords: cancer risk index, medical x-ray examination, dosimetry, health physics)

INTRODUCTION

The term risk is the probability of occurrence of hazardous event or phenomenon. For example, the probability of developing cancer after exposure to potential carcinogens or getting involved in auto crash after taking alcohol. Every human endeavor constitutes a level of risk or the other. Presently, society is increasingly aware that medical procedures expose the public, personnel and patient to risks of harm. Therefore, in any individual case of risk estimation, it is necessary to have accurate knowledge of radiation dose to the entire exposed organs.

The mechanism that leads to adverse health effects after ionizing radiation exposure are not fully understood. Ionizing radiation has sufficient energy to change the structure of molecules, including DNA, within the cells of the body. Some of these molecular changes are so complex that it may be difficult for the body's repair mechanism to mend them correctly. However, the evidence is that only small fraction of such changes would be expected to result in cancer or other health effects (The National Academies) [1].

Due to fast growing use of radiation in medicine, estimation of possible late effects of radiation, including potential cancer risk, become issues of great concern. Since physicians make the decision to order or perform a radiological procedure, it is very important to provide them with objective information about possible radiation associated risk. As result of this, Ivanov et al. [2] developed a methodology for estimating cancer risks of diagnostic medical exposure based on ICRP Publications 103 models [3]. Organ dose, age, and gender are used as basic parameters. This model could be used for simple and complex procedures.

According to the ICRP model [2], in an unexposed population, the basic risk factor is the background cancer mortality or incidence rate denoted as λ_o (the annual number of cancer deaths or cancer cases per 100,000 populations). Due to exposure to radiation, λ_o increases by $\delta\lambda$, the overall cancer mortality or incidence rate λ is:

$$\lambda = \lambda_o + \delta\lambda \qquad (1)$$

but

$$\lambda_o = \lambda_o\,(a,l,s,t) \qquad \textbf{(2)}$$

Where *l* is the tumor site, *a* is age, *s*, gender and calendar time *t.*

The radiation associated increment depend on radiation dose, *D* from other sources beside the background , attained age *a*, tumor site *l*, gender s, and the age at exposure g:

$$\delta\lambda = \delta\lambda\,(g,a,l,s,D) \qquad \textbf{(3)}$$

and Equation 1 becomes:

$$\lambda\,(g,a,l,s,D,t) = \lambda_o\,(a,l,s,t) + \delta\lambda\,(g,a,l,s,D) \qquad \textbf{(4)}$$

The radiation increment $\delta\lambda$ is an excess absolute risk (EAR) for the attained age *a*, exposure age *g* and radiation dose *D*.

The knowledge of the value of EAR could be used in the estimation of the lifetime attributable risk (LAR) of developing cancer at the *l* site after single exposure to dose *D* at the age *g*. The LAR (*g,l,s,D*) is a sum of values of excess of absolute risk for the attained age. It can also be defined as additional cancer risk above and beyond baseline cancer risk. LAR can be calculated for specific as well as for all cancer combined [4]. However, it is necessary to take into account the "healthy" survivor function, the probability that an unexpected individual will be alive and free of cancer of the site *l* from age *g* to the age *a*.

The value of LAR can be computed using:

$$LAR\,(g,l,s.D) = \frac{1}{DDREF}\; x \sum_{a=g}^{a_{max}} S(s,l,g,a) x\; EAR(g,a,l,s,D) \qquad \textbf{(5)}$$

Where S (s,l,g,a) is a healthy survivor function, for solid cancers, risks are divided by a dose dose and dose rate effectiveness factor (DDREF). This factor is taken as 2 [3,5].

In addition to the LAR of cancer mortality or incidence, one can use an attributable risk fraction, ARF, of mortality or incidence of cancer at the site *l* in males or females exposed to dose *D* at the age. Mathematically, *ARF* is the ratio of lifetime attributable risk to the overall lifetime risk of mortality or incidence:

$$ARF\;(g,l,s,t,D) = \frac{LAR\;(g,l,s,D)}{LAR\;(g,l,s,D) + BR\;(g,l,s,t)}\; x\;100\% \qquad \textbf{(6)}$$

Where *BR (g,l,s,t)* is a lifetime background risk of site specific cancer mortality or incidence, It can be calculated from the exposure age g. The background risk of cancer incidence rate is estimated by summing up background incidence rates with allowance for the disease-free lifetime from the age of exposure g. The background risk of cancer mortality rates is estimated by summing background mortality rates with allowance for the probability of being alive from the age at exposure g. We have undertaken the study to estimate the rate of cancer incidence/mortality resulting from medical diagnostic examinations carried out in southwestern Nigeria.

In the general case:

$$BR(g,l,s,t) = \sum_{a=g}^{a_{max}} \lambda_o(a,l,s,t) x\; S(s,l,g,a) \;, \qquad \textbf{(7)}$$

Where $S(s,l,g,a)$ is the probability of disease-free life of unexposed population from age g to age *a* if the background risk of incidence is calculated, and $S(s,l,g,a)$ is the probability of unexposed population being alive from age g (age at exposure) to age *a* (attained age) if the background risk of mortality is estimated.

MATERIALS AND METHODS

For easy calculation of ARF(ARF^{inc}, ARF^{mort}), values of lifetime attributable risk of cancer incidence and mortality (LAR^{inc}, LAR^{mort}) of males and females exposed to 1 mGy for different age groups (0-80 yr) per 10,000 population are tabulated based on ICRP 103 [3] and Preston *et al*. [6]. Additionally, lifetime background risk of cancer incidence and mortality BR (BR^{inc} and BR^{mort}) are also tabulated elsewhere [2].

In the estimation of ARF, knowledge of the organ dose, D number of organs found per site is essential. However, LAR^{inc} and LAR^{mort} are calculated by multiplying the specific organ dose,

D by the tabulated life attributable risk of cancer incidence/mortality for the individual (male or female) exposed to 1 mGy at the relevant age per 10,000 population. Summation of the LAR^{inc} or LAR^{mort} for different organs at a particular site (e.g. chest-lung, breast, esophagus, stomach and liver) is obtained. The results of LAR^{inc} or LAR^{mort} obtained were used with BR^{inc} or BR^{mort} (from risk table in [2]) to calculate ARF^{inc} or ARF^{mort} using Equation 6.

The organ dose, D used to calculate lifetime attributable risk (LAR) of cancer incidence and mortality in the study was estimated using DoseCal Software. This software was extensively used for patient organ dose measurements in diagnostic radiology, and it produced reliable results in previous studies [7, 8]. Thermo-luminescent dosimeters (TLD) were used to measure the entrance surface dose (ESD) during the diagnostic examinations. The ESD was converted to organ dose, D.

RESULTS

Tables 1 - 10 are the results of the calculated LAR and ARF for both cancer incidence and mortality for 10, 000 of the population: 5-yr old girl (chest PA), 7-yr old boy (chest PA), 42-yr old man (chest PA), 46-yr old woman (chest PA), 44-yr old man (pelvis AP), 55-yr old woman (pelvis AP), 63-yr old man (abdomen AP), 56-yr old woman (abdomen AP), 54 yr old man (lumbar spine AP), and 48 yr old woman (lumbar spine AP).

In Tables 1-10, Column 1 indicates the organs within the sites exposed to radiation during patient examination. Column 2 is the organ dose calculated during irradiation. The third and fourth columns are the expected life attributable risk (incidence and mortality) calculated, while the fifth and sixth columns show the attributable risk fractions (ARF). An attempt was made to make the results of LAR calculated meaningful; it was extrapolated to a population of Southwestern, Nigeria. The results of extrapolation of data shown in Tables 1 to 10 are given in Figures 1 to 10. The results in Tables 1 to 10 are based on population of 10, 000, they are extrapolated to the population of 35.5 million people found in the south west geo-political zone of Nigeria [9]. The Figures show different types of cancer: Figures 1 - 4 (lung, breast, esophagus, and stomach, liver); Figures 5 - 10: (bladder, liver, colon, stomach, lung).

Both the number of incidence (occurrence) and mortality (death) resulting from an exposure are shown. The blue bars indicate the incidence rate and the red, bars, the mortality rate. The distribution of life attributable risk (LAR), incidence and mortality for all solid cancer based on population of 35.5 million is presented in Figure11. Ten representative patients of different ages and four procedures were considered. The procedures are: chest (A-D), pelvis (E and F), abdomen (G and H) and lumbar (I and J). Similarly, the blue bar represents the number of expected cancer incidence, and the red bar indicates the number of death expected from the exposure. Furthermore, Figures 12 - 16 present the plots of attributable risk fraction (ARF) against attained age for a girl exposed at age of five. The plots show the distribution of ARF starting from the age when exposed (5 yr) through different attained age up till 80 year.

Figure 12 shows the incidence of lung cancer; Figure 13 is the plot for the incidence of breast cancer; Figure 14 describes the characteristics of the incidence of liver cancer at different attained age following a single exposure. The ARF (%) plot as against the attained age for the incidence of esophagus cancer is presented in Figure 15. The incidence is highest at the age of 60 year. Figure 16 is the ARF for incidence of stomach cancer. The ARF decreases gradually to the minimum before rising again beyond 70 years.

Table 1: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 5 year-old Girl after a Chest PA Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	ARF^{inc} (%)	ARF^{mort} (%)
Lung	0.47	0.0725	0.0712	0.0200	0.0241
Breast	0.12	0.0638	0.0289	0.00890	0.0148
Easophagus	0.16	0.00232	0.00230	0.00460	0.00490
Stomach	0.076	0.0148	0.0102	0.00560	0.00792
Liver	0.15	0.00600	0.00550	0.00510	0.00671
All solid cancer	--	2.245	1.0136	---	----
$ARF_{total}^{inc} = 0.0101$ $ARF_{total}^{mort} = 0.0158$ $ARF_{total}^{in,solid} = 0.0773$ $ARF_{total}^{mort,solid} = 0.0695$					

Table 2: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 7-year old Boy after a Chest PA Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Lung	0.87	0.0699	0.0616	0.00961	0.0102
Breast	0.21	0.0	0.0	0.0	0.0
Easophagus	0.32	0.00797	0.00590	0.00678	0.00512
Stomach	0.17	0.0241	0.0125	0.00487	0.00514
Liver	0.34	0.0293	0.0257	0.0118	0.0151
All solid cancer	--	2.623	1.388	--	--
$ARF_{total}^{inc} = 0.00826$ $ARF_{total}^{mort} = 0.00033$ $ARF_{total}^{in,solid} = 0.0387$ $ARF_{total}^{mort,solid} = 0.00513$					

Table 3: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a 42-year old Man after a Chest PA Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Lung	0.945	0.0869	0.0766	0.01170	0.01242
Breast	0.170	0	0	0	0
Easophagus	0.422	0.00591	0.00543	0.004924	0.004611
Stomach	0.206	0.0101	0.00526	0.002024	0.002137
Liver	0.420	0.0122	0.00512	0.004898	0.003026
All solid cancer	--	0.9798	0.5188	--	--
$ARF_{total}^{inc} = 0.00720$ $ARF_{total}^{mort} = 0.0080$ $ARF_{total}^{in,solid} = 0.0469$ $ARF_{total}^{mort,solid} = 0.0144$					

Table 4: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a 46-year old Woman after a Chest PA Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Lung	0.797	0.139	0.137	0.0392	0.0464
Breast	0.136	0.00854	0..00385	0.00135	0.00211
Easophagus	0.338	0.00518	0.00505	0.0101	0.0106
Stomach	0.163	0.00849	0.00588	0.00339	0.00466
Liver	0.345	0.00441	0.00409	0.00376	0.00506
All solid cancer	--	1.0065	0.4544	--	--
$ARF_{total}^{inc} = 0.01179$ $ARF_{total}^{mort} = 0.02128$ $ARF_{total}^{in,solid} = 0.03681$ $ARF_{total}^{mort,solid} = 0.03182$					

Table 5: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a 44-year old Man after a Pelvis AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Bladder	2.51	0.108	0.0411	0.0427	0.0594
Liver	0.092	0.00276	0.00242	0.00110	0.00143
Colon	1.28	0.0941	0.0505	0.02435	0.03168
Stomach	0.15	0.00735	0.00380	0.00147	0.00151
Lung	0.0028	0.000258	0.000226	0.0000347	0.0000366
All solid cancer	--	2.23	1.1785	---	---
$ARF_{total}^{inc} = 0.00999$ $ARF_{total}^{mort} = 0.00778$ $ARF_{total}^{in,solid} = 0.0617$ $ARF_{total}^{mort,solid} = 0.0564$					

Table 6: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a 55- year old Woman after a Pelvis AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Bladder	0.68	0.0169	0.004766	0.0215	0.0175
Liver	0.026	0.000197	0.000182	0.000174	0.000236
Colon	0.35	0.00557	0.00281	0.00182	0.00202
Stomach	0.041	0.00128	0.000884	0.000541	0.000727
Lung	0.000821	0.00012	0.000119	0.0000358	0.000422
All solid cancer	--	0.3841	0.1734	--	--
$ARF_{total}^{inc} = 0.0000112$ $ARF_{total}^{mort} = 0.00000691$ $ARF_{total}^{in,solid} = 0.0155$ $ARF_{total}^{mort,solid} = 0.0128$					

Table 7: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 63-year old Man after an Abdomen AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	ARF^{inc} (%)	ARF^{mort} (%)
Bladder	3.420	0.0643	0.0245	0.0271	0.0342
Liver	1.425	0.0117	0.0103	0.00587	0.00739
Colon	2.000	0.0478	0.0256	0.0138	0.0168
Stomach	2.560	0.0398	0.0206	0.00864	0.00878
Lung	0.064	0.00391	0.0034	0.000559	0.000583
All solid cancer	--	0.927	0.491	--	--
$ARF_{total}^{inc} = 0.00868$ $ARF_{total}^{mort} = 0.00706$ $ARF_{total}^{in,solid} = 0.0249$ $ARF_{total}^{mort,solid} = 0.0279$					

Table 8: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 56-year old Woman after an Abdomen AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	ARF^{inc} (%)	ARF^{mort} (%)
Bladder	8.25	0.206	0.0579	0.261	0.212
Liver	3.55	0.0272	0.0252	0.0241	0.0326
Colon	5.61	0.0893	0.0449	0.0292	0.0324
Stomach	6.21	0.192	0.133	0.0809	0.109
Lung	1.93	0.284	0.278	0.0846	0.0989
All solid cancer	--	4.0185	1.814	--	--
$ARF_{total}^{inc} = 0.0745$ $ARF_{total}^{mort} = 0.0425$ $ARF_{total}^{in,solid} = 0.162$ $ARF_{total}^{mort,solid} = 0.135$					

Table 9: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 54-year old Man after a Lumbar Spine AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	ARF^{inc} (%)	ARF^{mort} (%)
Bladder	1.01	0.0321	0.0122	0.0127	0.0173
Liver	1.36	0.0244	0.0214	0.0103	0.0134
Colon	1.59	0.0763	0.0406	0.0203	0.0256
Stomach	2.33	0.0726	0.0375	0.0149	0.0153
All solid cancer	--	1.540	0.816	--	--
$ARF_{total}^{inc} = 0.00759$ $ARF_{total}^{mort} = 0.0176$ $ARF_{total}^{in,solid} = 0.00433$ $ARF_{total}^{mort,solid} = 0.0394$					

Table10: Lifetime Attributable Risk of Cancer Incidence and Mortality for 10,000 Population and Etiologic Fraction of Cancer Incidence and Mortality for a ≈ 48 year old Woman after a Lumbar Spine AP Radiographic Imaging.

Organ	Organ dose (mGy)	LAR^{inc}	LAR^{mort}	$ARFi^{inc}$ (%)	ARF^{mort} (%)
Bladder	0.64	0.0238	0.00609	0.0291	0.0224
Liver	0.86	0.0111	0.0102	0.00943	0.0126
Colon	1.01	0.0211	0.0133	0.00481	0.00928
Stomach	1.48	0.0771	0.0533	0.0112	0.00885
All solid cancer	--	1.787	0.807	---	--
$ARF_{total}^{inc} = 0.0172$ $ARF_{total}^{mort} = 0.0219$ $ARF_{total}^{in,solid} = 0.0654$ $ARF_{total}^{mort,solid} = 0.0565$					

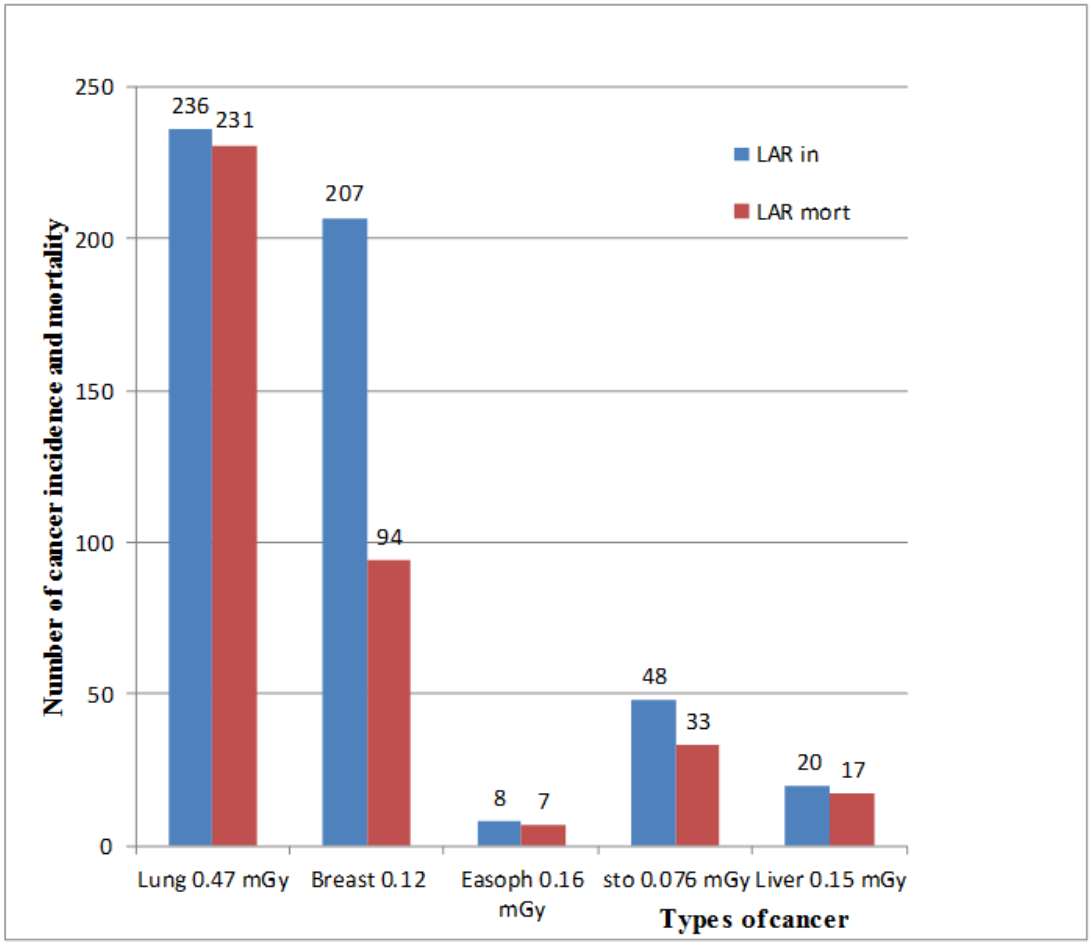

Figure 1: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (5 yr old Girl Chest PA Radiograph).

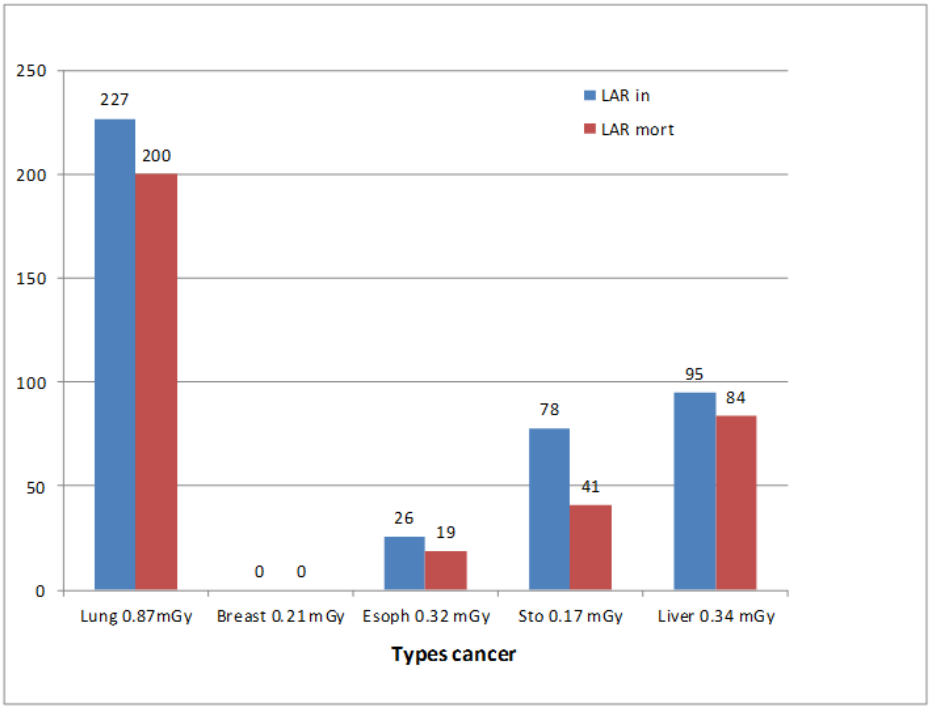

Figure 2: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (7 yr old Boy Chest PA Radiograph)

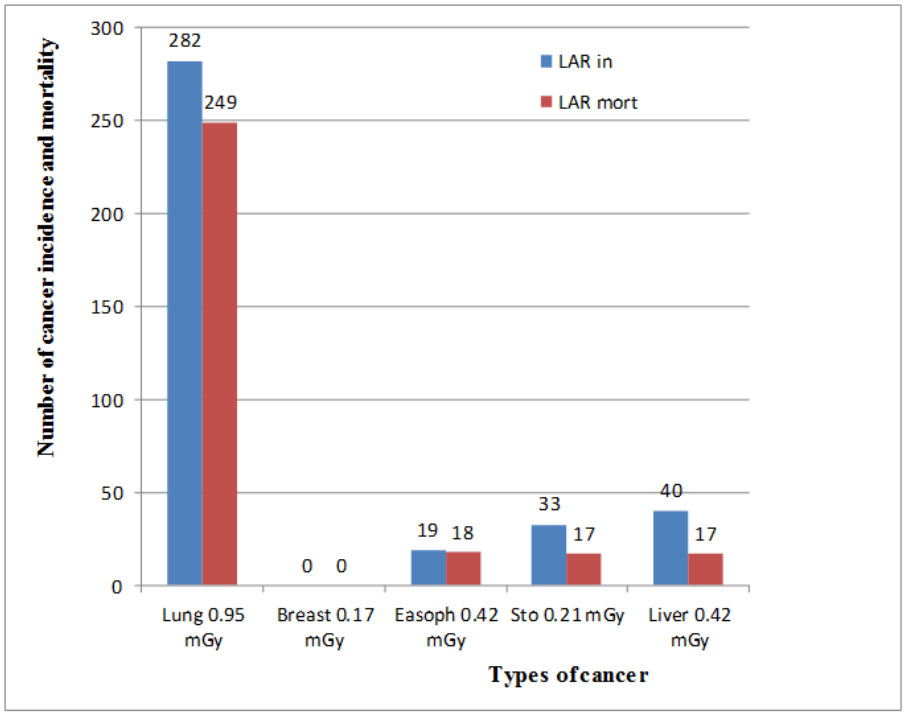

Figure 3: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (42 yr old Man Chest PA Radiograph).

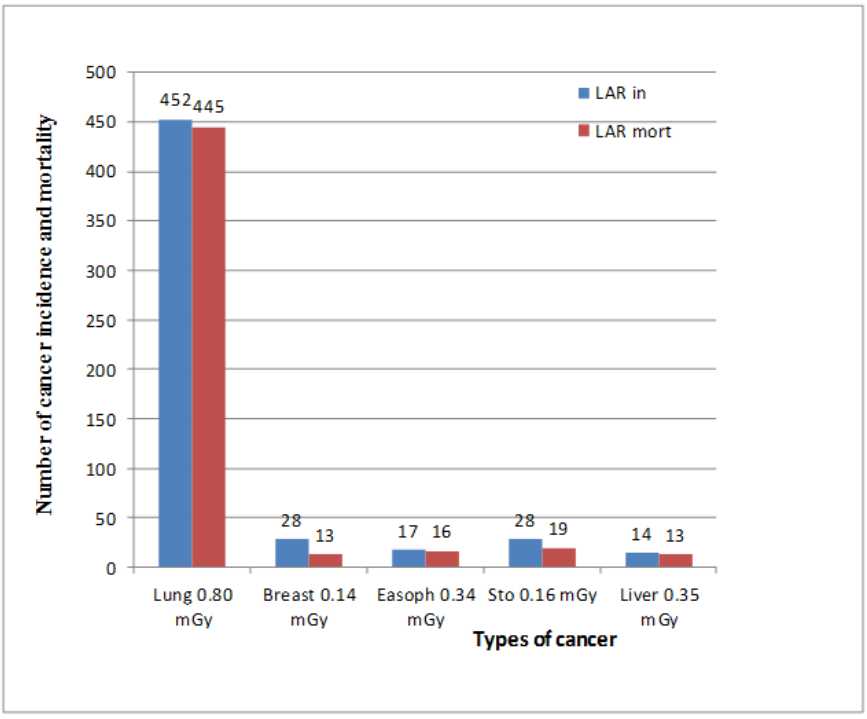

Figure 4: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (46 yr old Woman Chest PA Radiograph).

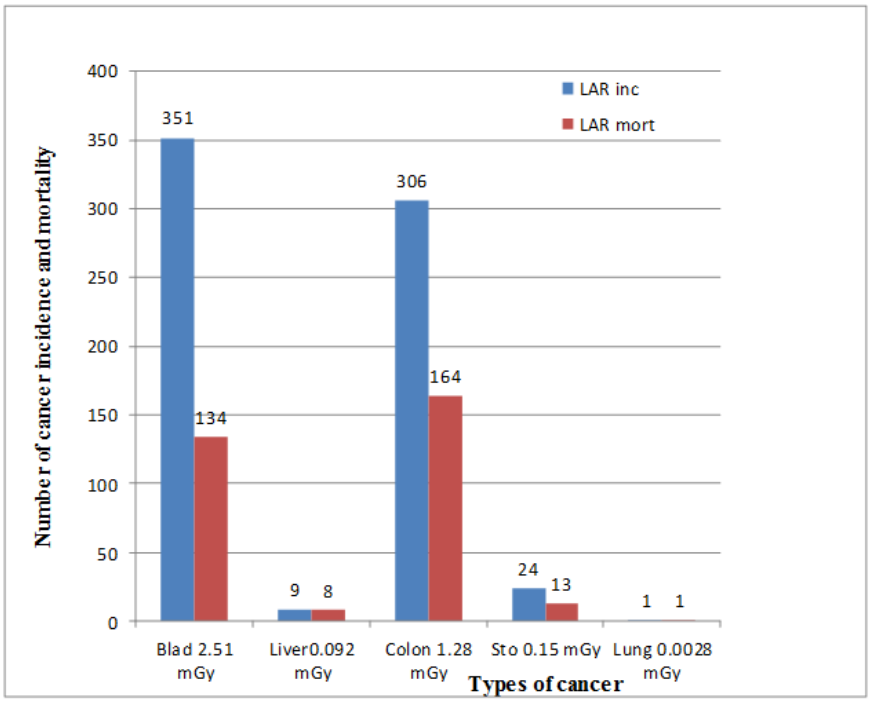

Figure 5: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (44 yr old Man Pelvis AP Radiograph).

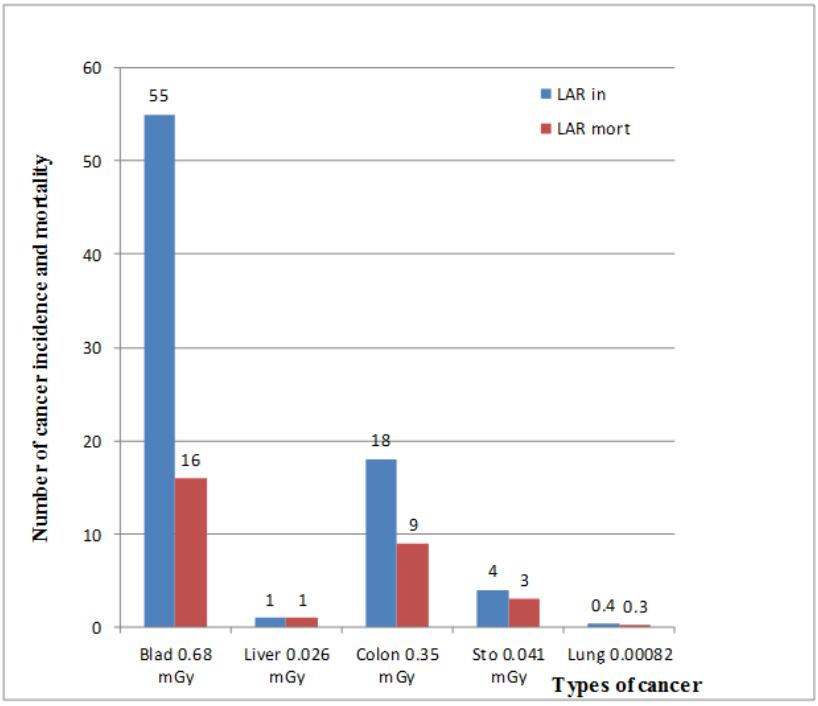

Figure 6: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (55 yr old Woman Pelvis AP Radiograph).

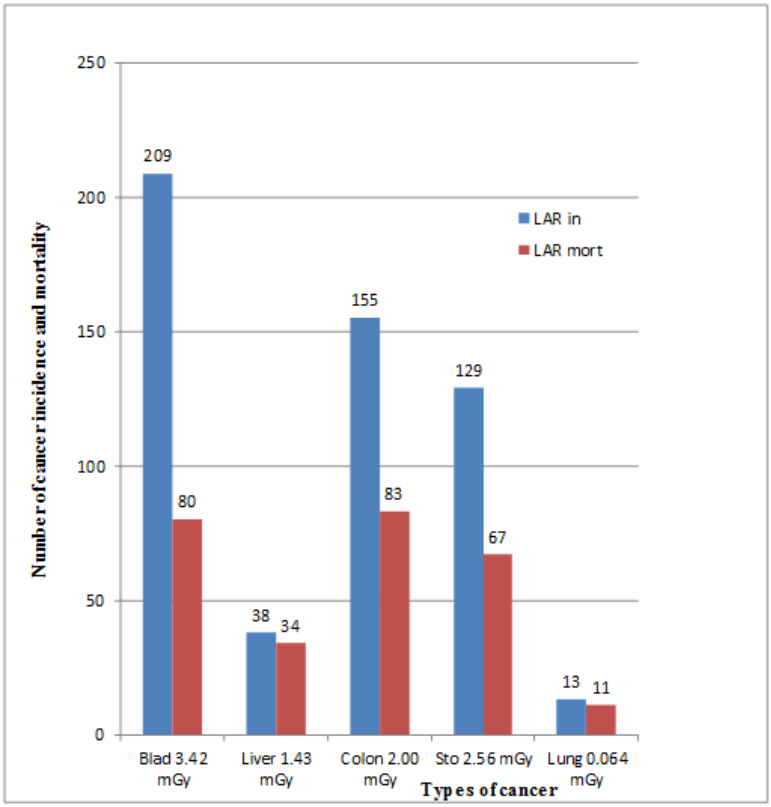

Figure 7: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (63 yr old Man Abdomen AP Radiograph).

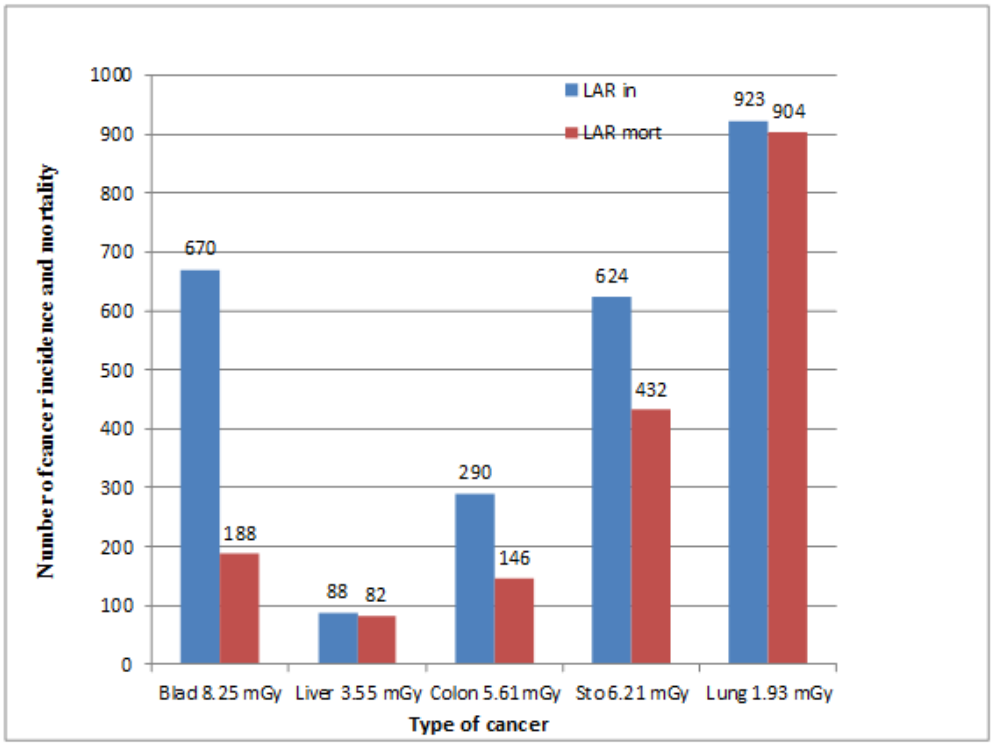

Figure 8: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (57 yr old Woman Abdomen AP Radiograph).

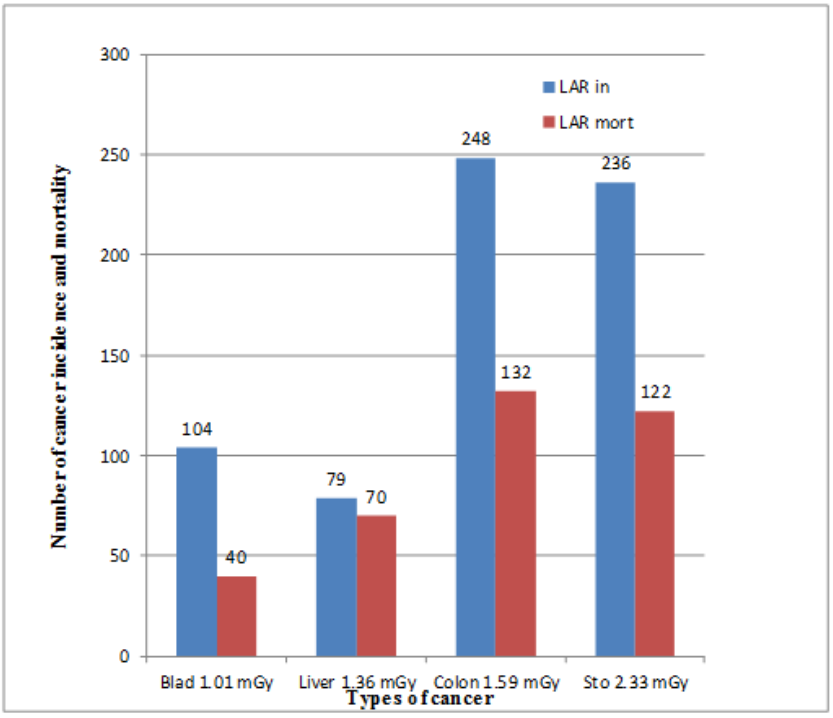

Figure 9: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (54 yr old Man Lumbar Spine AP Radiograph).

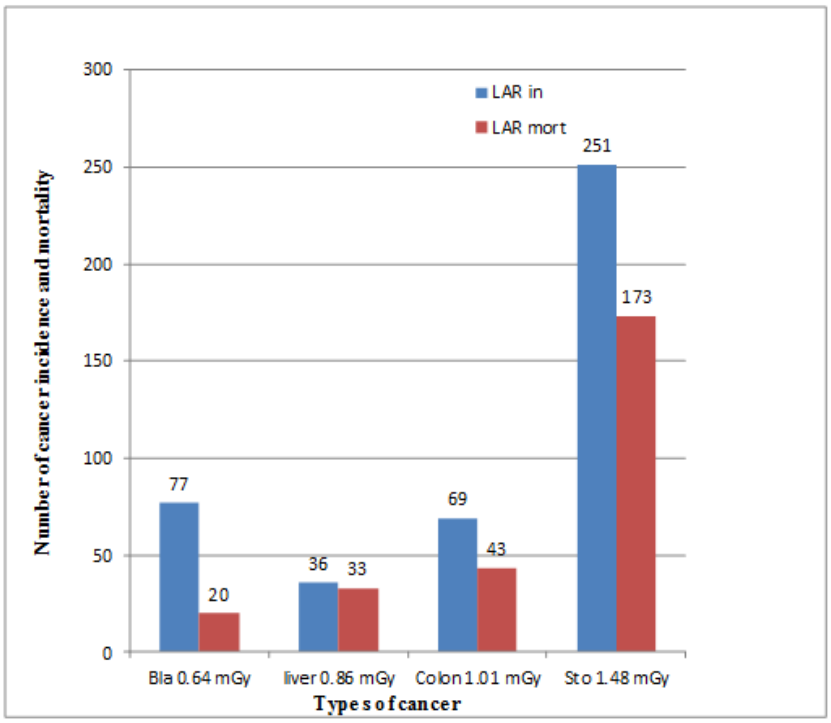

Figure 10: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (48 yr old Woman Lumbar Spine AP Radiograph.

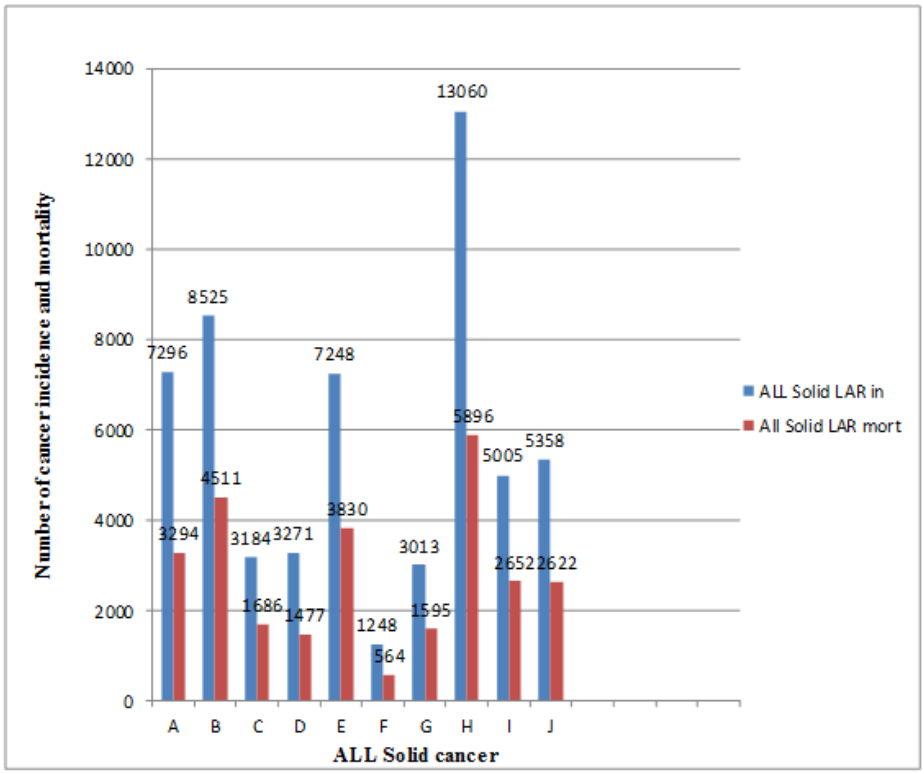

Figure 11: Distribution of LAR (incidence and mortality) for a Population of 35.5 Million in SW, Nigeria (for Ten Representative Patients and Four Procedures, Chest (A-D), Pelvis (E&F), Abdomen (G&H), Lumbar Spine (I & J)

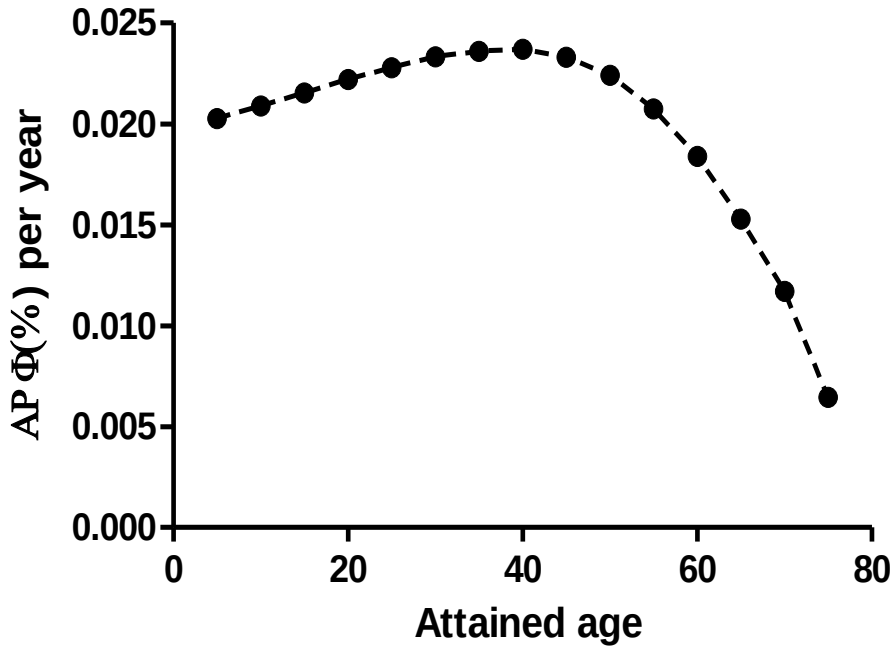

Figure 12: Attributable Risk Fraction for Incidence of Lung Cancer following a Single Exposure of ≈ 5-years old Girl with a Dose of 1.32 mGy from a Conventional Chest Radiography.

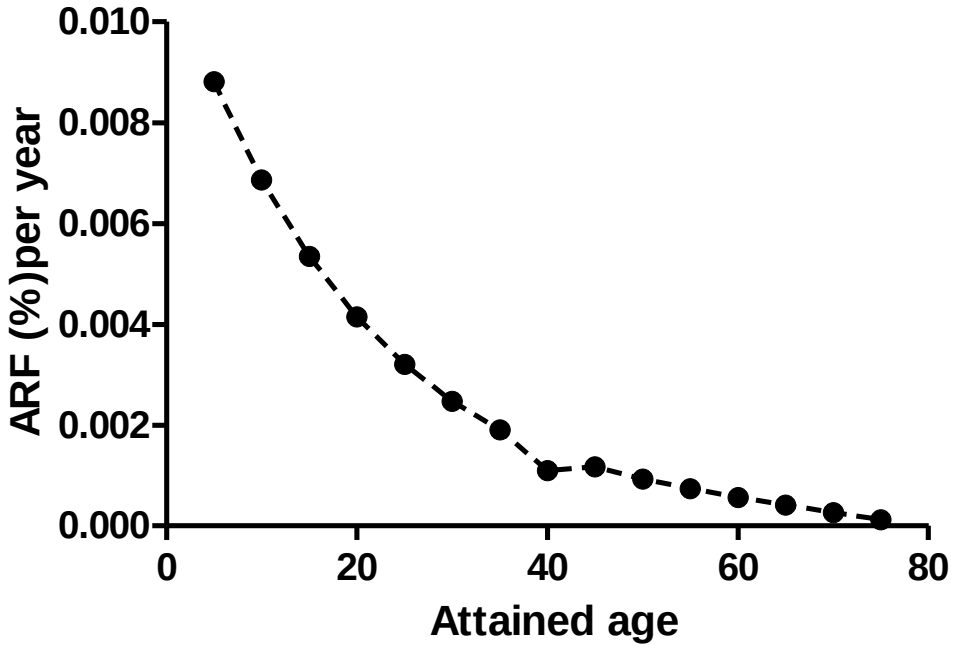

Figure 13: Attributable Risk Fraction for Incidence of Breast Cancer Following a Single Exposure of ≈ 5-years old Girl with a dose of 1.32 mGy from a Conventional Chest Radiography.

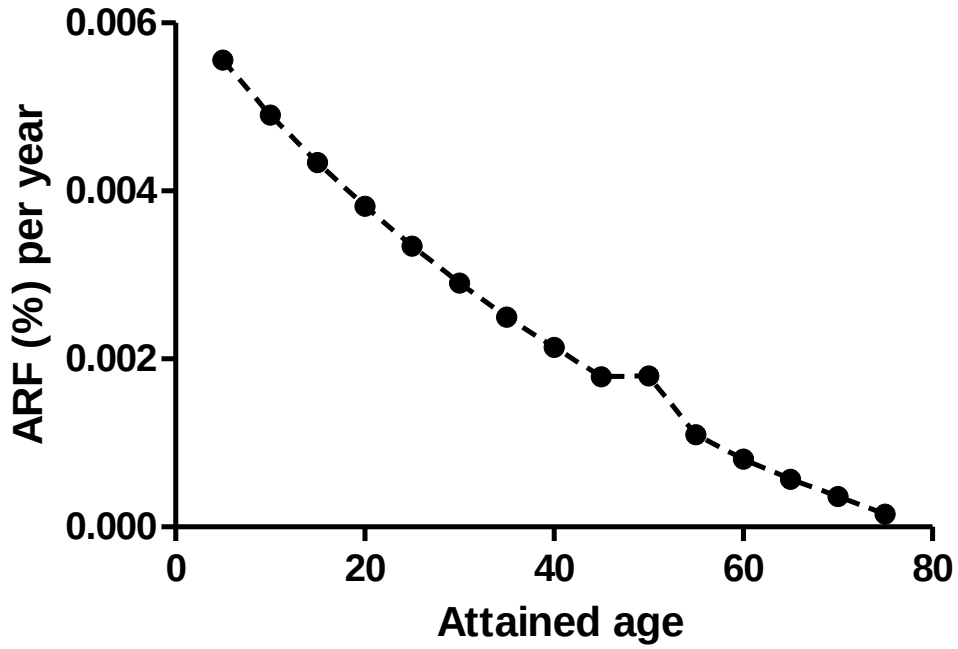

Figure 14: Attributable Risk Fraction for Incidence of Liver Cancer following a Single Exposure of ≈ 5-years old Girl with a Dose of 1.32 mGy from a Conventional Chest Radiography.

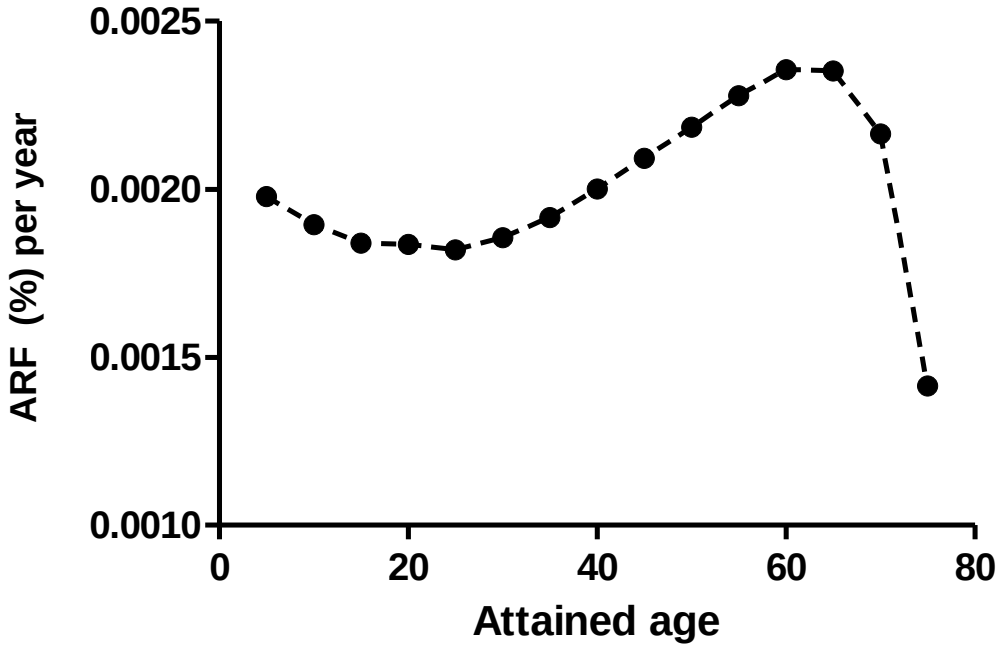

Figure 15: Attributable Risk Fraction for Incidence of Esophagus Cancer Following a Single Exposure of ≈ 5-years old Girl with a Dose of 1.32 mGy from a Conventional Chest Radiography.

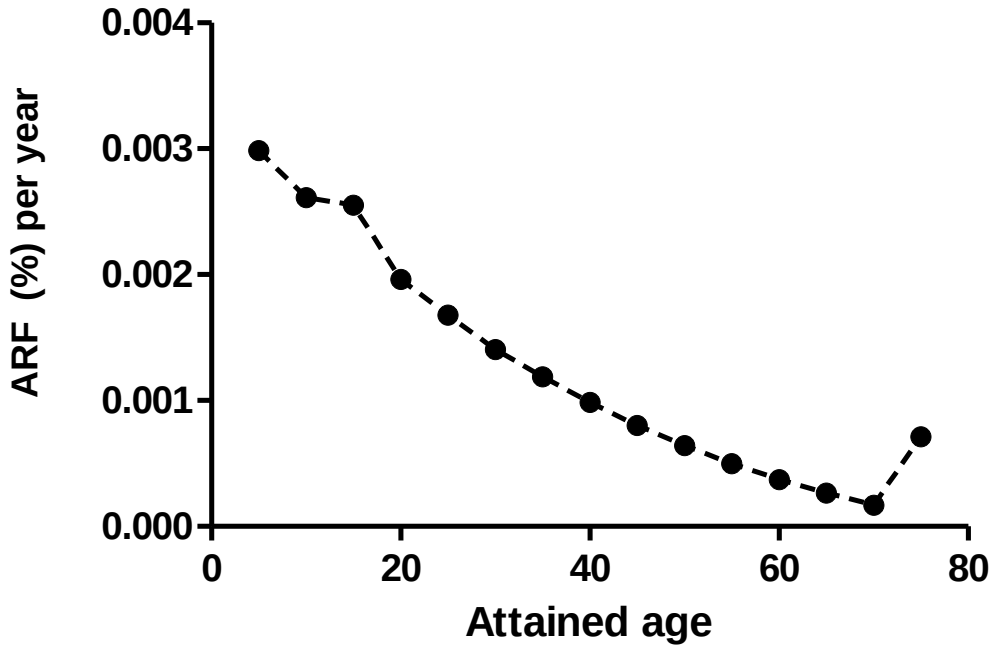

Figure 16: Attributable Risk Fraction for Incidence of Stomach Cancer following a Single Exposure of ≈ 5-years old Girl with a Dose of 1.32 mGy from a Conventional Chest Radiography.

DISCUSSION AND CONCLUSION

It is evident from Table 2 (7-year old boy) and Table 3 (42-year old man) that LAR and consequently ARF for breast cancer are zero. This is an indication that the probability of incurring breast cancer in either male pediatrics or male adult is zero. The cancer incidence and mortality estimated in this study are based on a small population of 10,000 people; therefore, low values of LAR (incidence), LAR (mortality), ARF (incidence) and ARF (mortality) were obtained for each organ (Tables 1- 10 – rows 2-5 and columns 3-6) . However, appreciable values were obtained for solid cancer. The results of LAR (incidence) and LAR (mortality) obtained for annual rate of solid cancer using a population of 10,000 are: ≈ Table 1 (2 1); Table 2 (3 1): Table 3 (1 0); Table 4 (1 0); Table 5 (2 1); Table 6 (0 0); Table 7 (1 0); Table 8 (4 2); Table 9 (2 1); Table 10 (2 1).

Based on a population of 10,000 people, the result showed no solid cancer incidence/mortality is expected when a 55 year old woman is exposed during pelvis AP examination (Table 6). The highest LAR (incidence) and LAR (mortality) occurrence is recorded during the exposure of 56 year old woman undergoing abdomen AP examination (Table 8) of a population of 10,000 people.

In an attempt to make the results more meaningful, data in Tables 1-10 were extrapolated to a population of 35.5 million people in the Southwestern (SW) Nigeria. The results are shown in Figures 1- 10 for different organs.

Four different procedures were extrapolated to a population of 35.5 million, these are chest PA, pelvis AP, abdomen AP and lumbar spine AP. Figures 1 – 4 show the results of four patients (5-yr old girl, 7-yr old boy, 42-yr old man and 46-yr old woman) who underwent upper trunk (chest PA), medical examinations and received different doses of radiation. In addition, Figures 5 and 6 included 44 yr old man and 55 yr old woman whose pelvises were examined. Figures 7 and 8 involved 63 yr old man and 57 yr old woman examined during abdomen AP procedure and finally, Figures 9 and 10 included 54 yr old man and 48 yr old woman who underwent lumbar spine AP examination.

Figures 1 - 4 show that the incidence and mortality of lung cancer are generally more pronounced during the chest PA examination. Besides, it is noteworthy from the comparisons of Figure 1 (5-yr old girl) and Figure 2 (7-yr old boy) that the incidence/mortality of lung cancer for the female (236/231) is greater than for male (227/200) population even at a lower female organ dose of 0.47 mGy as against 0.87 mGy for male. Similar trend is found in Figure 3 (42-yr old male) and Figure 4 (46-yr old female). It is clear that the incidence/mortality of lung cancer in female exposed to lower dose of 0.80 mGy is higher than male who received dose of 0.95 mGy by factor of 1.6 (incidence) and 1.8 (mortality) respectively. In addition, the mortality rate of lung cancer is higher in female than in male population. This is evident from the comparisons of Figures 1 and 4 (females) with Figures 2 and 3 (males).

Another important feature of chest examination as indicated in this study is that, breast cancer incidence/mortality is more pronounced in young female than adult female even at a lower dose. The reason for higher incidence of lung and breast cancer during the chest examination could be attributed to the fact that the two lie in the path of the primary X-ray beam especially in young people with smaller body sizes. Other organs such as liver and stomach are close by, as a result the incidence are relatively lower than lung and breast cancers. These suggest adequate collimation and shielding during examinations to prevent exposure of organs that are not of great interest during diagnosis.

Owing to the possibility of higher incidence/mortality of lung cancer in female population especially the young (pediatrics), and the increase in carcinogenic effect, it is important to exercise utmost care in the choice of exposure factors and the projection when carrying out chest examinations. In any situation in which alternative imaging technique can be adopted, it is necessary to do so to avoid the use of X-rays. More importantly, in any case where the patient can be adjusted (tilted at an angle) such that examination can be carried out and the female will not face the beam directly it should be done.

Adoption of postero-anterior (PA) is better than antero- posterior (AP) projection when examining a female chest owing to the presence of the breast. Apparently, the location of the organ from the site of exposure is one of the factors that determine the extent of the cancer incidence and its mortality. The study of Kumaresan et al. [10] among Indians indicates that the dose to the patient using the AP view has inferior image quality and is of greater dose than the dose using the PA view.

With regards to pelvis AP examination, a comparison of Figures 5 and 6 shows that cancer incidence and mortality in bladder and colon are dose- and site-dependent. The trend therefore, requires that the dose be as low as reasonably achievable without impairing the image quality. Dose delivered to the sensitive organs should be adequately reduced. Figures 7 and 8 also attest to the fact that the incidence/ mortality is dose-dependent. However, the nature of Figure 8 shows that certain organs are more prone to cancer incidence and mortality than others. This is evident in Figure 8 which shows that in spite of the fact that, a relatively lower dose of 1.93 mGy is delivered to the lung as against higher dose of 8.25 mGy to the bladder, yet higher annual lung cancer rate of incidence/mortality is still recorded.

Although the organs irradiated are relatively farther from the lung, yet the greatest effect is recorded in the lung. This shows that good collimation and shielding are required to prevent nearby organs whose images are not required for a specific diagnosis. Another important characteristic of cancer mortality shown in Figure 8 is that certain cancers lead to greater percentage mortality. The percentage of mortality recorded in different organs are: bladder: 21.1%; liver: 93.1%; colon: 50.3%; stomach: 69.2% and lung 98.5%.

Result of lumbar spine examination shown in Figures 9 and 10 indicate that the incidence/mortality of cancer in three out of four organs is dose dependent. However, in female with relatively lower dose 1.48 mGy recorded higher incidence/mortality of stomach cancer. The rate of mortality is also higher in the female subjects within the Southwestern Nigeria. Based on the sensitive nature of the organ (stomach), it is essential to explore other alternative imaging techniques during the examination of the lumbar spine AP of the female patients.

Adopting alternative techniques will to a larger extent reduce the cancer incidence and mortality among the female subjects. The result shown in Figures 9 and 10 (stomach cancer) also point to the fact that it is gender dependent, since female with lower doses displayed a higher incidence

and mortality of stomach cancer than her male counterpart. The difference between the incidence and mortality implies that, it is not all the cancer incidence that might lead to death if detected early and treated; however, it could lead to other deleterious effects

There are other incidences of non-solid cancers such as leukemia and other detrimental effects which reduce the quality of life of individuals in the population studied. Besides, the cost of taking care of the health effects resulting from exposures; it also affects the family and the society finance. Other effects could be in form of cardiovascular diseases and genetic effects.

The distribution of incidence and the corresponding mortality for all solid cancer (lung breast, stomach, liver, bladder, esophagus) for sample of 10 subjects undergoing four different procedures: chest (subjects A-D); pelvis (subjects E and F); abdomen (subjects G and H); lumbar spine (subjects I and J) are shown in Figure 11. The risk of solid cancer for each subject per 10, 000 was extrapolated to a population of 35.5 million. The distribution shows that highest incidence/ mortality is recorded in H (abdomen AP).

The calculated annual incidence of solid cancer for H is 13,060 (0.39%) people, while the corresponding mortality rate is 5,896 people from a population of 35.5 million. The mortality rate is less than half of the incidence rate. This is obtained from the examination of a 56 year old female subject who underwent abdomen AP examination. The distribution is closely followed by subject B (chest PA examination) with incidence and mortality being equal to 8,525 (0.24%) and 4,511, respectively. The least recorded is found in pelvis AP (F) with incidence and mortality rate of 1,248 (0.038%) and 564 subjects in a population of 35.5 million. The percentages of mortality emanating from solid cancer range from 45.2 – 53.0 %. The specific numerical information provided in this study would help the referring Physicians, Radiologists and Imaging Staff make the best possible decisions on justification and optimization of examination.

Figures 12 -16 are the plots of ARF against the attained age based on ICRP models. The figures demonstrate the dependence of ARF of lung cancer, breast cancer, liver cancer, esophagus, and stomach cancer incidence on the attained age following exposures of a 5 year old girl to a dose of 1.32 mGy from conventional chest X-ray. In Figure 12, the ARF_{lung}^{inc} increase steadily until it reaches the highest value in the neighborhood of 40 years and thereafter the risk fraction declined gradually at old age. The ARF of incidence of lung cancer at attained age of 40 year is higher than the fraction of incidence at the age of 75year by a factor of about 3.4.

As for the breast cancer, the ARF_{breast}^{inc} decreases steadily with attained age until the age of 40 year, after which a short plateau (40-43 years) was recorded (Figure 13). Moreover, the fraction of incidence decreases further until it further dropped to near zero at old age of 75 years. The characteristics of plot of the ARF_{liver}^{inc} against attained age (Figure 14) is similar to the characteristics found in breast cancer, except that the drop in incidence fraction with attained age is not as steep as the breast and the short plateau occurred at later age of 45-50 years. Similar trend is found in Figure 16 (stomach cancer) except that the constant phase occurred between 10-15 years, however, an interesting feature is seen at old age (70 years) where the $ARF_{stomach}^{inc}$ incidence increased sharply.

The feature found in esophagus (Figure 15) is quite unique. The ARF_{easoph}^{inc} starts with low incidence of about 0.0020 (of population of 10,000) per year and falls gradually until it reaches the age of 15 year from where a constant (plateau) incidence phase is found between 15 and 25 year. Thereafter, the incidence increases steadily to the highest value at attained age of 65 years where it finally dropped to a low value at age of 75 years. This is an indication that ARF increased from age of 25 to 65year (40 years span).

The trend of plots found in this study is in agreement with the one reported in earlier work [5]. The increase in attributable risk fraction (ARF) incidence at early age is more pronounced in lung cancer (5-40years) and for esophagus cancer, the incidence increase from age of 25-65 years. However, the rates of increase or decrease of risk of cancer incidence vary between the different organs. These trends call for dose optimization during diagnostic imaging.

REFERENCES

1. The National Academies. 2002. *BEIR VII: Health Risk from Exposure to Low Levels of Ionizing Radiation*. The National Academies

2. Ivanov, V.K., A.F. Tsyb, F.A., Mettler, A.N. Menyaylo, and V.V. Kashcheev. 2012. "Methodology for Estimating Cancer Risks of Diagnostic Medical Exposure: with an Example of the Risks Associated with Computed Tomography". *Health Phys*, 103 (6):732-738.

3. International Commission on Radiological Protection. 2007a. *The 2007 Recommendations of the International Commission on Radiological Protection*. Elsivier; ICRP Publication 103; Ann ICRP, 37 (2-4). Elsevier: Amsterdam, The Netherlands.

4. Smith-Bindman, R., J. Lipson, R. Marcus, K. Kim, M. Mehesh, R. Gould, A, Berrington de Gonzalez, and D.L. Miglioretti. 2009. "Radiation Dose Associated with Computed Tomography Examinations and the Associated Lifetime: Attributable Risk of Cancer". *Arch Intern Med*. 69 (22):2078-2086.

5. Wall, B.F, R. Haylock, J.T.M., Jansen, M.C. Hillier, D. Hart, and P.C. Shrimpton. 2011. "Radiation Risk from Medical X-Ray Examinations as a Function of the Age and Sex of the Patient". Health Protection Agency, Center for Radiation, Chemical and environmental Hazards. Chilton: Didcot..

6. Preston, D.L., E. Ron, S. Tokuoka, S. Funamoto, N. Nishi, M. Soda, K. Mabuchi, and K., Kodama. 2007. "Solid Cancer Incidence in Atomic Bomb Survivor: 1958-1998". *Radiat Res*., 168:1-64.

7. Suliman, I.I. and H.A. Elshiekh. 2008. "Radiation Doses from some Common Pediatric X-Ray Examinations in Sudan". *Radiat Prot Dosim*. 132(1):64-72.

8. Mohammadain, K.E.M, L.A.R. da Rosa, A.C.P. Azevedo, M.R.N. Guebel, M.C.B. Boechat, and F.I. Habani. 2004. "Dose Evaluation for Pediatric Chest X-Ray Examination in Brazil and Sudan: Low Dose and Reliable Examinations can be Achieved in Developing Countries". *Physics in Medicine and Biology*, 49:1017-1031.

9. National Bureau of Statistics. 2013. "Population of Soutwestern Nigeria". NBS: Abuja, Nigeria.

10. Kumaresan, M., J. Kumar, K. Biju, A. Choubey, and S. Kantharia. 2011. "Measurement of Entrance Skin Dose and Estimation of Organ Dose During Pediatric Chest Radiography". *Health Phys.* 100(6): 654-657.

SUGGESTED CITATION

Olowookere, C.J., N.N. Jibiri, T.O. Bello, and C. Aborishade, S. 2016. "Estimation of Cancer Risks Arising from Medical Exposure to Ionizing Radiation of a Population in Southwestern Nigeria". *Pacific Journal of Science and Technology*. 17(1):241-257.

Pacific Journal of Science and Technology