

# Determination of Effective Dose for Sensitive Organs and Cancer Risk in Contrast-Enhanced Abdominal CT-Scan

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**Abstract:** A study has been conducted on the Effective Dose of Sensitive Organs and the Risk of Cancer in Contrast to Abdominal CT-Scan Examination to determine the effective dose of sensitive organs and the risk of cancer in male and female patients. This study was conducted at Bali Mandara Hospital, and data was used, namely, 60 CT-scans of the Abdomen in contrast to patient examination data. The sensitive organs of concern in this study are the stomach, colon, bladder, and liver. To determine the effective dose value of sensitive organs, the equivalent dose value (*HT*) is multiplied by the value (*WT*) in each sensitive organ. From the calculation results obtained, it is known that the highest dose is received by the stomach and colon with a value of  $9.90 \times 10^{-1} \pm 3.94 \times 10^{-1}$  mSv for male patients and  $8.82 \times 10^{-1} \pm 2.27 \times 10^{-1}$  mSv for female patients. To find out the cancer risk value in each organ for male and female patients is done by multiplying the equivalent dose value (*HT*) by the value (*rt*) in each organ in adult patients. From the results obtained, patients with the highest risk of cancer are male patients with the highest risk, namely the colon organ, with a risk of  $79,16 \times 10^{-4}$  %. From the results obtained, an analysis was carried out to compare the cancer risk in male and female patients for each organ using the Independent T-Test. From the results obtained, it was found that there was a difference in cancer risk between the two patients, where male patients have a greater risk of cancer than women, with the highest average difference in cancer risk, namely  $0.00086 \pm 0.00066$  % in the colon organ.

**Keywords:** Cancer risk; Contrast abdominal; CT- Scan; Effective dose; Sensitive organs

## Introduction

According to the International Atomic Energy Agency (IAEA), Radiation is energy that moves from one place to another in the form of waves or particles. Today, radiation is widely used in various fields to support the improvement and development of performance in these fields, one of which is in the medical field. Radiation in the medical field is used in treatment or therapy and in diagnosis to detect disease. One of the most common types of radiation used in the medical field is X-rays. In the medical field, X-rays are used as a radio diagnostic device to see and detect

disease before further action related to therapy or treatment planning is taken (IAEA, 2024).

One of the radiodiagnostic devices that uses X-rays as its source is the Computer Tomography Scan better known as the CT-Scan. CT-Scan can create cross-sectional images of the body based on the absorption of X-rays in body slices, the results of which are displayed on a computer. In general, CT-Scan is the same as other radio diagnostic devices; however, compared to other diagnostic tools such as X-ray machines, which also use X-rays as their source, CT-Scan has many advantages, including the image capture technique and the image results obtained on CT-Scan where compared to 2-dimensional image results that can only be produced by

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X-ray machines, CT-Scan machines can create 3-dimensional images so that the images produced by CT-Scan machines are better than X-ray machines Rontgen (Wahyuni & Amalia, 2022). Based on this CT-Scan imaging, CT-Scan is recognized as a very reliable diagnostic tool in medical imaging and is widely used to improve patient examination results (Ohene et al., 2023). CT-Scan examinations sometimes use contrast media given to patients undergoing scans. This aims to enhance the quality of the images and improve the visualization of various organs in diagnostic imaging. In addition, contrast media are used in CT-Scan examinations to make it easier to see the difference between the normal anatomy of tissue so that diseases or abnormalities in the patient's body can be properly identified. One type of CT-Scan examination that uses contrast media is an abdominal examination, where an abdominal examination is one that looks at the human stomach (Ohene et al., 2020).

Although CT-Scan scanning provides enormous benefits in diagnostics for patients, CT-Scan examination can pose potential risks to organs exposed to radiation. In a CT-Scan examination, the organs being examined will be exposed to radiation from all angles so that many organs, including healthy organs, are involved during irradiation. One CT-Scan examination that can provide a large dose is an abdominal scan. A relatively high dose is usually obtained in abdominal scanning, especially using contrast media. This is because there are repeated scans, as many as two scans, once in the arterial phase and once in the venous phase (Cao, 2022), (Klein et al., 2022).

In the abdomen, many healthy organs will be exposed to radiation in a CT-Scan. Healthy organs that are exposed to radiation are called Organs at Risk (OAR), or, in Indonesia, are called sensitive organs. These sensitive organs have different sensitivities to radiation exposure. High radiation doses in CT-Scans can cause potential cancers such as leukaemia. In addition to high radiation doses, radiation exposure received by patients during CT-Scans can also cause potential cancer in organs exposed to radiation even though the radiation dose received is low (Shao et al., 2020), (Oktar, 2023).

In a study conducted by Sipul in 2020 on Determining the Effective Dose of Organs at Risk for Head Irradiation with a Siemens 128 Slice CT-Scan, it was found that the effective dose of sensitive organs or organs at risk received by male patients was greater than that of female patients. Another study by Khoiriyah in 2020 on Estimating Radiation Doses and Risk Factors in Abdominal Computed Tomography Scans found that large radiation can interfere with organ function. The effects can be in the form of organs that do not function optimally, the emergence of tumours or cancer in

organs, and other tissue damage effects and hereditary effects.

Regarding the influence and effects that can occur in X-ray radiation scanning for patients in CT-Scan examinations, it is necessary to research Determining the Effective Dose of Sensitive Organs and the Risk of Cancer in CT-Scan Examination.

## Method

### Location and Time of Research

Research on the effective dose in contrast abdominal CT Scan examination was conducted at the Radiology Installation of Bali Mandara Hospital from October 2024 to November 2024.

### Research Variables

The variables used in this study are divided into 3, namely independent variables, dependent variables and control variables. The independent variables used in this study are the value of the time current strength (mAs) and the magnitude of the tube voltage (kV). The dependent variables is CTDI<sub>vol</sub> and The control variable are number of slices, slice thickness, and scan length.

### Research Tools

The equipment used in this research are CT Scan Machine and computer. The CT Scan machine used is a Siemens 128 Slice MC7-172 model with serial number 669351671 located in the Radiology Installation of RSUD Bali Mandara and the computer in this study is used to perform the Scanning process, reconstruction or data processing, display images and to analyze images.

### Data analysis

From the data received from the computer, the total effective dose value in the contrast-enhanced abdominal CT-scan for each patient is calculated using Equation 1.

$$DE = DLP \times k \tag{1}$$

Note:

DE : Effective dose (mSv)

DLP : Dose length product (mGy.cm)

k : Empirical weight of body tissue (mSv/mGy.cm)

After determining the total effective dose in the contrast-enhanced abdominal CT-scan, each patient's effective dose for sensitive organs is subsequently calculated. Before this, the equivalent dose (H<sub>T</sub>) is calculated using Equation 2.

$$H_T = CTDI_{vol} \times W_R \tag{2}$$

Note:

CTDI<sub>vol</sub> : Computed tomography dose index volume (mGy)

W<sub>r</sub> : Radiation weighting factor

After knowing the equivalent dose, the effective dose of sensitive organs was calculated using the equivalent dose value and organ weight factor ( $W_t$ ) by ICRP 103. The effective dose value of sensitive organs was obtained using Equation 3.

$$E = H_T \times W_t \tag{3}$$

Note:

$E$  : Effective dose of sensitive organ (mSv)  
 $W_T$  : Weighted tissue

Calculations are also carried out to determine the cancer risk (R) after knowing the effective dose value of sensitive organs. Cancer risk is obtained using Equation 4.

$$R = H_T \times r_t \tag{4}$$

To determine the percentage of cancer risk, the obtained result is multiplied by 100%. Mathematically, it can be expressed as:

$$R = (H_T \times r_t) \times 100\% \tag{5}$$

Note:

$H_T$  : Equivalent dose (mSv)  
 $r_t$  : Cancer risk coefficient (100 mSv)<sup>-1</sup>

The calculations are carried out by ICRP 103 guidelines.

After obtaining the cancer risk for each patient, all the values obtained are averaged, and the standard deviation is sought using the equation below:

$$\Delta x = \sqrt{\frac{\sum(x_i - \bar{x})^2}{(n-1)}} \tag{6}$$

Note:

$\Delta x$  : Standard deviation of variable x  
 $x_i$  : Variable x to i-measured  
 $\bar{x}$  : Mean of variable x  
 $n$  : A lot of data

An independent T-test was conducted to compare the cancer risk between male and female patients. The Independent T-test is performed to observe the average of the two unbound sample groups. The formula for the Independent T-test to determine the calculated t-value can be seen in the equation below.

$$t_{count} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1+n_2-2} \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \tag{7}$$

Note:

$\bar{x}_1$  : Mean of the first sample (male patients)  
 $\bar{x}_2$  : Mean of the second sample (female patients)  
 $S_1$  : Standard deviation of the first sample group  
 $S_2$  : Standard deviation of the second sample group  
 $n_1$  : A lot of first sample data  
 $n_2$  : A lot of second sample data

In this study, the test was also conducted by comparing the average cancer risk in male and female patients and finding the probability value (p-value) using SPSS Statistics 25 software or Microsoft Excel. Independent T-testing was conducted using 95% confidence and 5% significance levels. The proposed statistical hypothesis is:

$H_0$ : There was no difference in the average risk of cancer in male and female patients

$H_1$ : There is a difference in the average risk of cancer in male and female patients

Based on the calculations, the value of  $t_{count}$  will be compared with  $t_{table}$ . The criteria for rejecting the hypothesis  $H_0$  are as follows:

If  $t_{count} < t_{table}$ , then  $H_0$  will be accepted and  $H_1$  will be rejected.

If  $t_{count} > t_{table}$ , then  $H_0$  will be rejected and  $H_1$  will be accepted.

Additionally, the hypothesis will also be determined based on the p-value. The p-value obtained from the statistical test will be compared. The criteria for rejecting the hypothesis  $H_0$  for the p-value are as follows:

If p-value > 0.05, then the hypothesis  $H_0$  is accepted and  $H_1$  is rejected.

If p-value < 0.05, then the hypothesis  $H_0$  is rejected and  $H_1$  is accepted.

## Result and Discussion

The data obtained consists of 60 points divided into 30 male and 30 female patients. The following is the data for male patients undergoing contrast-enhanced abdominal CT-Scans.

**Table 1.** Research Data

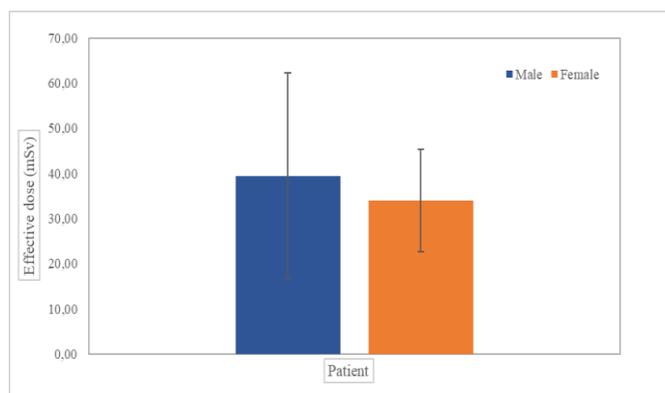
Patient Initial	Sex (M/F)	Age (Year)	Tube Voltage (kV)	Tube Current. Time (mAs)	CTDIvol (mGy)	DLP (mGy.cm)
JMD	L	71	130	526	11,63	3722
IWD	L	69	130	310	6,89	2156
NS	L	63	130	250	5,57	1773
INM	L	63	130	348	7,71	2592
JB	L	29	130	284	6,31	2045
MM	L	62	130	613	17,34	4450
MD	L	64	130	267	5,91	1878
IKS	L	37	130	297	6,61	2063

Patient Initial	Sex (M/F)	Age (Year)	Tube Voltage (kV)	Tube Current. Time (mAs)	CTDIvol (mGy)	DLP (mGy.cm)
IGS	L	60	130	216	4,82	1452
IWR	L	54	130	291	6,47	2086
IKSA	L	50	130	196	4,37	1349
MRI	L	34	130	277	6,15	1986
FF	L	34	130	469	10,37	3111
IKAS	L	36	130	294	6,53	2004
MM	L	54	130	626	13,83	4554
IWD	L	43	130	399	8,82	3164
IBN	L	63	130	439	11,81	2567
HM	L	47	130	552	14,30	3463
IKSR	L	65	130	316	7,03	3221
RJQ	L	32	130	412	9,13	2998
KUR	L	59	130	321	9,60	1770
INM	L	55	130	328	7,30	2266
ST	L	45	130	349	7,73	2634
SHR	L	51	130	489	10,84	9289
GE	L	33	130	304	6,75	2234
MDN	L	61	130	318	12,89	1579
WN	L	67	130	234	5,21	1861
IBAS	L	38	130	264	5,86	1822
GM	L	20	130	214	4,77	1406
KS	L	65	130	216	4,83	1471

After that, the overall effective dose value in the contrast-enhanced abdominal CT-Scan is calculated using Equation 1. The overall effective dose obtained is CTDIvol and DLP, and its standard deviation is determined. The results can be seen in Table 2 and Figure 1.

**Table 2.** Mean value and standard deviation DE, CTDI<sub>Vol</sub> and DLP.

Patient	Effective dose (mSv)	CTDIvol (mGy)	DLP (mGy.cm)
Male	39.48 ± 22.76	8.25 ± 3.28	2632.20 ± 1517.58
Female	33.93 ± 11.36	7.35 ± 1.89	2261.83 ± 757.03



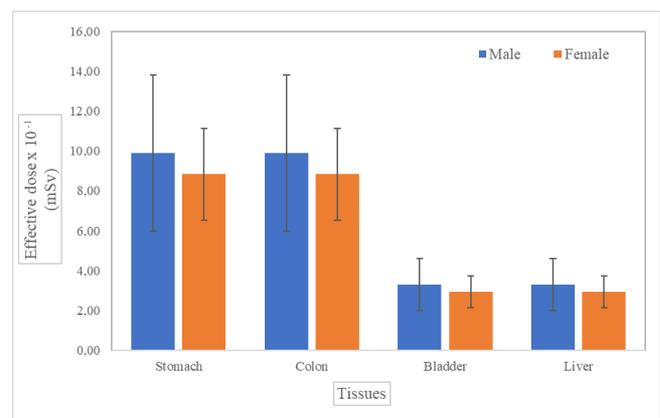
**Figure 1.** Comparison graph of the overall effective dose of abdominal CT-Scan examinations for male and female patients.

Next, the effective dose value is calculated for sensitive organs such as the stomach, colon, bladder, and

liver using the equivalent dose. The results obtained can be seen in Table 3 and Figure 2.

**Table 3.** Results of calculation of effective dose of sensitive organs

Sensitive Organ	Effective dose (mSv)	
	Male (10 <sup>-1</sup> )	Female (10 <sup>-1</sup> )
Stomach	9.90 ± 3.94	8.82 ± 2.27
Colon	9.90 ± 3.94	8.82 ± 2.27
Bladder	3.30 ± 1.31	2.94 ± 0.76
Liver	3.30 ± 1.31	2.94 ± 0.76



**Figure 2.** Comparison graph of effective doses for each patient's sensitive organs

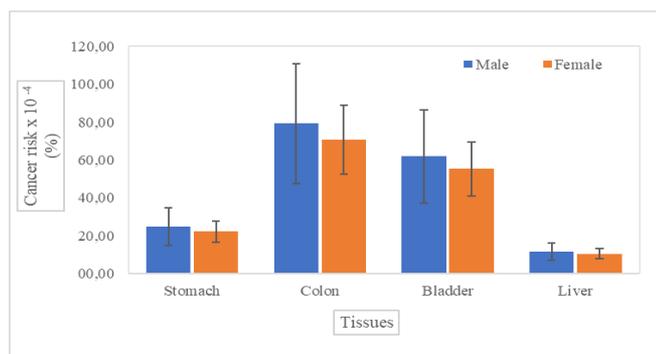
The results show that the effective dose for the most sensitive organs, both in male and female patients, is received by the stomach and colon, while the bladder and liver receive the effective dose for the least sensitive

organs. The results obtained support the research conducted by Oktar in 2023. This research found that the liver, which has the same organ weight as the bladder, receives the lowest dose compared to other organs. This is because this organ has a lower sensitivity to X-ray radiation than the colon, which has a high sensitivity to X-ray radiation. In addition to the low sensitivity possessed by each organ, another factor that can result in a higher dose to sensitive organs is the position of the organ itself, where the colon receives a greater dose compared to other organs because it is located at the central point of radiation during the abdominal CT-Scan examination.

After obtaining the effective dose values for each sensitive organ, the next step is to calculate the cancer risk for both male and female patients for each sensitive organ. The results obtained can be seen in Table 4 and Figure 3.

**Table 4.** The results of the cancer risk calculations for male and female patients.

Sensitive Organ	Cancer Risk (%)	
	Male ( $10^{-4}$ )	Female ( $10^{-4}$ )
Stomach	24.74 ± 9.85	22.06 ± 5.67
Colon	79.16 ± 31.52	70.59 ± 18.15
Bladder	61.85 ± 24.62	55.15 ± 14.18
Liver	11.54 ± 4.60	10.29 ± 2.65



**Figure 3.** Comparison chart of cancer risk between male and female patients for each organ

The results obtained indicate that the sensitive organ with the highest cancer risk is the colon, while the organ with the lowest cancer risk is the liver. The results are consistent with the research conducted by Ohene in 2023. In that study, it was found that in various cases during CT-Scan examinations, the colon received the highest radiation dose and had a higher cancer risk compared to other organs. The same results were obtained by the research conducted by Galinging in 2023, where it was found that the colon has a greater cancer potential than other organs, even though these organs have the same organ weight. This is due to the different cancer risk factors present in each organ, with

the largest cancer risk factor being associated with the colon. Subsequently, statistical tests were conducted to determine the average difference in cancer risk between male and female patients for each organ. Before this, the t-value was calculated. The results of the calculations can be seen in Table 5.

**Table 5.** The result of the calculation of  $t_{count}$

Sensitive Organ	$t_{count}$	$t_{table}$
Stomach	1.291	2.00172
Colon	1.291	2.00172
Bladder	1.291	2.00172
Liver	1.291	2.00172

Subsequently, testing was conducted using SPSS software to determine the p-value. The testing results are presented in Table 6.

**Table 6.** The result of the p-value calculation

Sensitive Organ	n	The average difference between male and female patients	p-value
Stomach	60	0.00027 ± 0.00021	0.202
Colon	60	0.00086 ± 0.00066	0.202
Bladder	60	0.00067 ± 0.00052	0.202
Liver	60	0.00012 ± 0.00010	0.202

From the results, it is obtained that the count is smaller than the table, and the p-value is greater than 0.05; thus, based on these results, it is concluded that hypothesis H0 is accepted, which means there is no difference in cancer risk between male and female patients. From the results obtained regarding the average difference between males and females, it is known that the average difference between male and female patients exists in each organ. From these results, it can be seen that there is no significant difference in cancer risk between male and female patients. From the average cancer risk results for each organ for both patient groups, both male and female, it is obtained that the highest cancer risk in all organs is found in the stomach, colon, bladder, and liver, with male patients having the highest cancer risk, particularly in the colon organ. The results are from the research conducted by Diah Sari in 2023. The results indicate that male patients have a higher risk of cancer compared to female patients. The greater cancer risk observed in male patients is attributed to several factors, including the higher doses received by male patients compared to female patients. Thus, the doses received are directly proportional to the risk faced by male patients.

### Conclusion

The effective dose in the stomach and colon for male patients is  $9.90 \times 10^{-1} \pm 3.94 \times 10^{-1}$  mSv, while for female patients it is  $8.82 \times 10^{-1} \pm 2.27 \times 10^{-1}$  mSv. The effective dose in the bladder and liver for male patients is  $3.30 \times 10^{-1} \pm 1.31 \times 10^{-1}$  mSv, and for female patients it is  $2.94 \times 10^{-1} \pm 0.76 \times 10^{-1}$  mSv. Male patients have a higher cancer risk than female patients, with the highest risk organ being the colon. However, the results indicate no significant difference in cancer risk between male and female patients, with the largest average difference in colon being  $0.00086 \pm 0.00066$  %.

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### Author Contributions

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### Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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