









ORIGINAL PAPER

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The influence of ODM technique on the radiation dose received by patients during head CT scan

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ABSTRACT

Introduction. Computed tomography (CT) is inexpensive radiological examination of high diagnostic effectiveness. However, common use of CT tests has led to increased exposure to ionizing radiation in the population.

Aim. To assess the effect of organ dose modulation (ODM) technique on the radiation dose received by patients during head CT scan.

Material and methods. A retrospective analysis of 120 tests in two groups of patients who had CT scans without and with ODM. Every group consisted of 60 people (30 women and 30 men in each). The ability to perform tests in two algorithms (without and with ODM) resulted from the fact that after installing the apparatus, tests were carried out using standard technique, and only then the ODM function was launched.

Results. We found that during examinations with ODM, patients received a reduced dose of ionizing radiation. The mean DLP value with ODM is 9.4% lower than the mean DLP value without ODM by comparing the tests with and without contrasting agent. The mean DLP value obtained in men using ODM was 11.9% lower than the mean dose without ODM, and in women this difference was 6.6%.

Conclusion. The mean DLP value received by men with ODM was by 11.9% lower than the mean dose without ODM, and in women this difference was 6.6%. Patients receive a lower dose both in tests with and without a contrasting agent compared to the tests where ODM was not used. A statistical significance of the obtained results was found.

Keywords. organ dose modulation, computed tomography, protection against ionizing radiation

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Participation of co-authors: A – Author of the concept and objectives of paper; B – collection of data; C – implementation of research; D – elaborate, analysis and interpretation of data; E – statistical analysis; F – preparation of a manuscript; G – working out the literature; H – obtaining funds

Received: 1.05.2018 | Accepted: 9.07.2018

Publication date: September 2018

Sobczyk J, Pusz-Sapa A, Wojtasik A, Gawęł G, Truskiewicz A, Guz W. *The influence of ODM technique on the radiation dose received by patients during head CT scan.* Eur J Clin Exp Med. 2018;16(3):198–203. doi: 10.15584/ejcem.2018.3.4

Introduction

Computed tomography (CT) is available and relatively inexpensive radiological examination of high diagnostic effectiveness. Multi-detector row CT scanners and shortened acquisition time have led to more frequent clinical use of CT. The result was a significant increase in the number of tests - it is estimated that it amounts to as much as 40% of all diagnostic examinations. In the past 25 years, worldwide, the number of nuclear medicine examinations has almost tripled, while the number of CT examinations has increased more than twenty times.¹

However, common use of CT tests has led to increased exposure to ionizing radiation in the population. United States citizens are exposed to ionizing radiation from medical devices almost six times higher than in 1980, and CT constitutes 45% of the total exposure to medical radiation in the USA, although it has only a 12% share in medical procedures.² Head CT is one of the most common CT examinations. Exposure to X-rays in this area has a twofold aspect. First of all, there are eye lenses which are an anatomical element particularly sensitive to X-rays. Secondly, it is the anatomical area with a high content of bone elements, hence the need to use X radiation of greater hardness which results in the emission of higher doses.³ In addition, in many clinical situations it is necessary to repeatedly examine the same patient. All these issues require the head CT scan to be performed in such a way that the patient is exposed to the lowest possible dose.

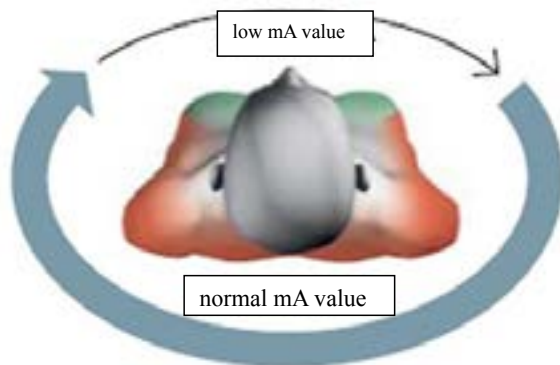


Fig. 1. Graphical principle of the ODM function.⁵

Reference: Siemens Healthcare, Guide to Right Dose

One of the ways of dose reduction, also in the case of CT scan of the head, is the use of the organ dose modulation (ODM) technique. This technique is based on automatic adjustment of the lamp current in real time, in order to obtain the optimum quality of the diagnostic image at the lowest possible dose, depending on the size and construction of the patient. Thus, the radiation dose is modulated to adapt to the image of the organ and the patient's body characteristics (Fig. 1) in order to

better manage the dose in relation to the anatomy of the examined patient.⁴

Aim

The aim of the study is to compare X-rays doses obtained during CT examinations performed in standard technique and ODM technique.

Material and methods

A retrospective analysis was performed in two groups of patients who had CT scans due to different clinical indications. Each group consisted of 60 people (30 women and 30 men in each). Patients had the examination performed using a 256-slice Revolution CT scanner by GE. The ability to perform tests in two algorithms (without and with ODM) resulted from the fact that after installing the apparatus, tests were carried out in the standard technique, and only then the ODM function was launched.

Group A - patients who had head CT scans without ODM; mean age was 66.7 (26 to 90 yrs).

Group B - patients who had head CT scans with the ODM; mean age was 62.5 (19 to 92 yrs).

The same protocol was used in all examinations. First, two preliminary images (Scout views) were taken with 250 mm coverage - the first in the antero-posterior projection (a-p), the other in the lateral projection. The transverse plane of slices was set through the nasal bridge and external auditory openings. A constant voltage of 120 kV and the examination time - 9 s (with the rotation time of the lamp-panel system - 1 s), pitch 1.0 were used. mA values were automatically selected - SmartmA 100-300 mA. The test was performed using 2.5 mm slices, the test range was 16 cm to cover the entire head. Noise Index in all examinations was at 2.5. All patients had the examination initially without and later with a contrasting agent. Dose Length Product (DLP) was recorded for each patient. DLP is the product of CT DIvol (in mGy) and scan length (in cm). CT DIvol is CT volume dose index expressed in the form of CT DIw divided by pitch factor (quotient of the displacement of the table during a complete revolution of the X-ray lamp and the thickness of a single slice). CT DIw is a weighted CT dose index that allows the assessment of the average dose in a single slice.

The variable distribution has been checked. It deviates from the normal distribution. Normalization by logarithm did not bring enough change. Therefore, non-parametric tests were performed. The Mann-Whitney U test was used to compare the mean DLP doses in the examinations without and with ODM, without contrasting agent and after its administration, as well as a

comparison of mean DLP doses with and without ODM between the sexes.

The Wilcoxon signed-ranks test was used to compare mean doses of DLP in the examinations without and with ODM in the groups of women and men. Statistical significance was defined at $p < 0.05$.

Results

After performing the test without and with the contrasting medium, the mean DLP values for groups A and B were calculated. The differences in mean DLP values between group A (the standard technique, without ODM) and B (with ODM) were analyzed. The results are shown in Figure 2.

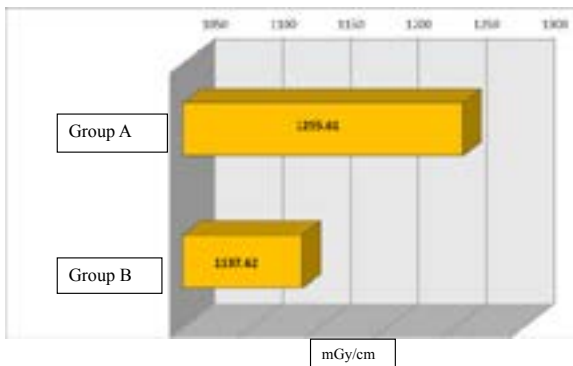


Fig. 2. Comparison of mean DLP values between groups A and B during CT scan without and with the contrasting agent

The mean DLP value for all patients during the head examination with ODM was 9.4% lower than the mean dose without ODM. The difference is 117.99 mGy/cm and is statistically significant ($p = 0.000007$).

Then the differences in mean DLP values for men in group A and B were analyzed. The results are shown in Figure 3.

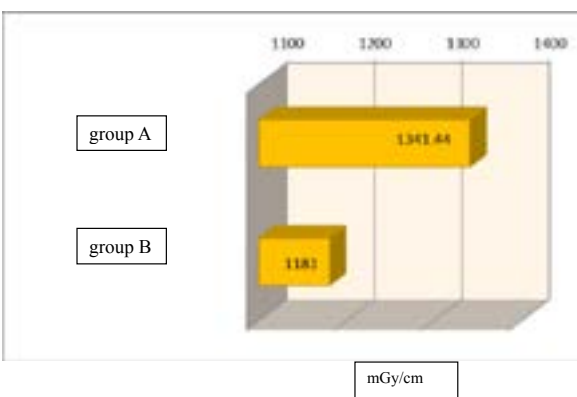


Fig. 3. Comparison of mean DLP values between groups A and B in men during CT scan without and with ODM

The mean DLP value in men during the head examination with ODM was 11.9% lower than the mean dose without ODM. The difference amounted to 160.44 mGy / cm and was statistically significant ($p = 0.0007$).

In the same way, the difference in doses of DLP received by women in group A and B was analyzed. The results are presented in Figure 4.

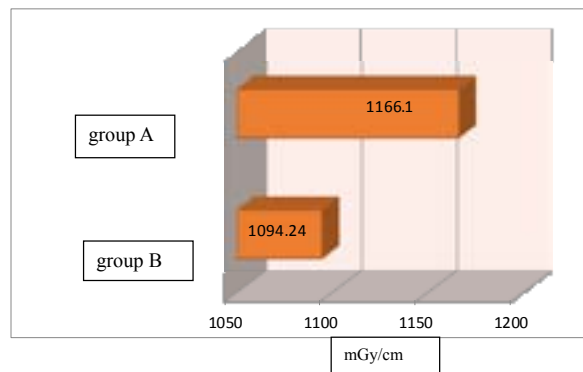


Fig. 4. Comparison of mean DLP values between groups A and B in women during CT scan without and with ODM

As in the group of men, women received by 6.6% lower dose of DLP when using ODM. The mean DLP dose with ODM was by 71.86 mGy / cm lower and the difference was statistically significant ($p = 0.006$).

Due to differences in mean values in the group of men and women, a comparison was made between both sexes.

Mean doses were compared in men and women during CT scan without and with a contrasting agent, without ODM and the results are summarized in Figure 5.

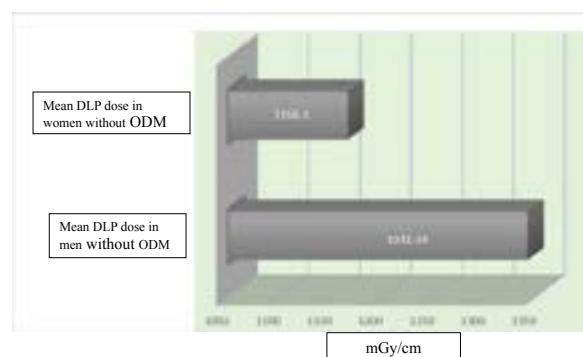


Fig. 5. Comparison of the mean DLP values between men and women in the CT examination without and with the administration of a contrasting agent, without ODM

The mean DLP dose without ODM in men was 1341.44 mGy/cm, whereas in women 1166.1 mGy / cm. The difference was 13% - 175.3 mGy / cm and was statistically significant ($p = 0.000001$).

An analogous comparison was made in case of ODM use. The results are shown in Figure 6.

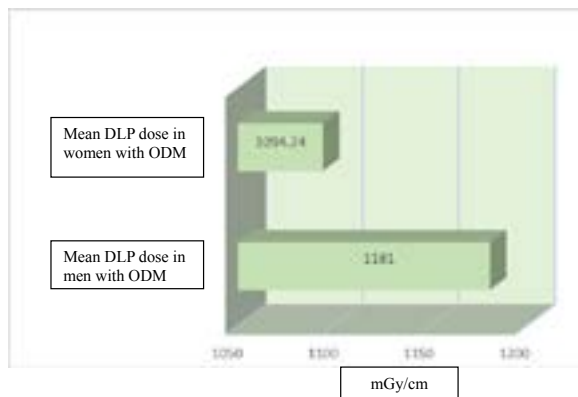


Fig. 6. Comparison of the mean DLP values between women and men in the CT examination without and with the administration of a contrasting agent, with ODM

The mean DLP dose with ODM in men was 1181 mGy /cm, whereas in women 1094.24 mGy /cm. The difference was 7.3% - 86.76 mGy / cm and was statistically significant ($p = 0.0072$).

Concluding, the difference in the values of received doses (DLP) during the CT examination between women and men in case ODM was not used amounted to 13% and in the case of ODM use, 7.3%.

Since a significant percentage of CT scans are performed without the use of a contrasting agent (most tests in case of injuries), an analogous analysis was made as for the first part of the study, except no contrasting agent was administered.

The mean DLP values for groups A and B were calculated. The differences in mean DLP values between group A (the standard technique, without ODM) and B (with ODM) were analyzed. The results are shown in Figure 7.



Fig. 7. Comparison of mean DLP values between groups A and B during CT scan without contrasting agent

The mean DLP value for all patients during head examination without ODM was 10.9% higher - 76.38 mGy

/ cm - than the value when ODM was used. The difference was statistically significant ($p = 0.000001$).

Discussion

A significant increase in the number of CT examinations worldwide allows better detection of pathological lesions. However, the widespread use of this method results in an increase in the level of X-ray doses in the patient population.

The number of CT apparatuses in the world are constantly increasing - although the number of apparatuses per 1 million inhabitants in individual countries is very diverse. The highest number of tomographs are in Japan (almost 103.1 per 1 million inhabitants). To compare, there are 17.2 CT apparatuses per 1 million inhabitants in Poland.⁶ In this way, the risk of cancer due to CT examinations also increases.⁷⁻⁹ However, dose levels in CT examinations (typical effective dose expressed in mSv in the case of head scan is 1.6 mSv) are significantly lower than the threshold dose for inducing deterministic effects, nevertheless they may affect the stimulation of gene mutations and carcinogenesis.¹⁰ Hence, doses generated in CT examinations may particularly pose a risk to pediatric patients, youth and adult women.^{11,12} Both doctors referring to examination as well as the patients and their benefactors are generally unaware of the doses of radiation received in the CT examination, its risk of carcinogenesis and the importance of reducing exposure in younger patients.^{13,14} Radiologists, who generally have a higher education in radiation biology and radiation risk, often have no direct relationship with patients who are imaged.¹⁵ It has been calculated that in the US, 700 people (including 170 children) die due to radiation-induced malignancies by CT scan of the head and abdominal region a year.¹⁶ The risk of breast cancer is doubled in women with two or more CT examinations before the age of 23.¹⁷

The latest epidemiological results and studies on animals suggest that dose thresholds causing deterministic effects (e.g. lens opacities that may eventually lead to cataracts) are or may be lower, than has been assumed.^{18,19} The radiation dose for the eye lens may vary between 10.6 and 25.5 mGy with an average value of 18.8 mGy.^{20,21}

Therefore, despite obvious benefits, limitations on the diagnostic CT tests (especially in children) are introduced because of their potentially dangerous oncogenic effects.²² The presented issue requires common analysis of radiologists, medical physicists, government legislative bodies and producers of CT equipment. CT staff began more accurately select protocols for individual types of examinations, individualizing them in relation to

specific patients. Two important principles have also been formulated:

1. Referral to CT examination must be well-grounded.
2. All technical aspects of the test must be optimized to achieve the required level of image quality while maintaining the lowest possible doses for every CT scan.²³

Manufacturers, in subsequent generations of CT devices, began to implement techniques to minimize radiation doses. Among various methods, one of more effective techniques is organ-dose modulation (ODM).²⁴

There are few publications describing the use of ODM and they mainly concern phantom research. The first results were presented in 2011 in the American Journal of Roentgenology. It was assessed that the use of ODM reduced the dose on the phantom surface by 27 - 50%, depending on the anatomical region (head or chest) without deterioration in image quality.²⁵

In 2012, studies were performed in which the influence of dose reduction on the eye lens using bismuth shielding and ODM protection was compared. Dose reduction with ODM was found to be higher. The dose in the standard CT scan for the eye lens was 32.16 mGy, with bismuth shielding 23.66 mGy, and in case of ODM 22.39 mGy.²⁶

In 2015, the results of experimental research on anthropomorphic thoracic and head phantoms were presented. Dose reduction was found in all dosimeter locations with reference to SmartmA (angular modulation and Z axis) 31.3% (nipple), 20.7% (lungs), 24.4% (heart), 5.9% (spine), 18.9% (eye) and 10.1% (brain). On the other hand, simulation studies with voxelized phantoms have shown average reduction of doses: 33.4% (nipple), 20.2% (lungs), 18.6% (spine), 20.0% (eyeball) and 7.2% (brain).²⁷

In 2016, another assessment of ODM effectiveness was published - it was found that CTDIvol decreased by about 20%, increasing the noise index by about 14%.²⁸

Whereas the producer (General Electric) declares in the manual of the CT apparatus used to perform the tests analyzed in the presented paper, that in the case of head examination - dose reduction up to 30% is expected with the reservation that the accuracy of ODM will be affected by the exact positioning of the patient. Therefore, incorrect positioning of the patient in the a-p direction will affect the effectiveness of dose reduction for radiosensitive organs.²⁹

Our calculations have also shown that the use of ODM reduces the dose of DLP both in women and men. The mean DLP value for all patients during the head examination (without and with contrasting agent) with ODM was 9.4% lower than the mean dose without ODM. The mean DLP value in men during the head examination with ODM was 11.9% lower than the mean dose without ODM and in women, the difference was 6.6%.

Mean DLP doses without using ODM before and after administration of the contrasting agent were higher than the doses obtained using ODM and were higher by 10.9% and 6.2% respectively. In addition, significant differences were observed when comparing mean doses received by women and men during tests without and with ODM. The difference in tests without ODM was 13% in favor of women, with ODM it was 7.3% also for women. The results of the quoted studies concerned tests performed on phantoms. In the results of our study, when patients were examined, no such significant values of DLP dose reduction were found. Nevertheless, it was found that it is reasonable to use ODM protocols at each head CT scan. This seems particularly important in view of the very large number of patients referred for CT scanning of the head which are not always well justified.³⁰

Conclusion

1. Results of the paper confirmed that the use of ODM technique reduces the dose of X-radiation received by the patient during the CT scan of the head.
2. We found that the reduction of DLP in patients is lower than in phantom studies.
3. The mean DLP value using ODM was reduced in the study group by 9.4% and the difference is statistically significant.
4. The mean DLP value obtained by men using ODM was by 11.9% lower than the mean dose without ODM, and in women this difference was 6.6%. Both results are statistically significant.
5. The mean DLP dose without the use of ODM during the examination without contrast was higher by 67.38 mGy / cm (10.9%) than the doses obtained by the subjects when ODM was used.
6. A difference was found in the values of received doses (DLP) during the CT examination between women and men. In case ODM was not used, DLP values in the group of women were 13% lower and in the case of ODM use by 7.3%. The difference was statistically significant.
7. The use of ODM technique should be necessary in all CT scans of the head.

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