SINFONIA

# Medical X-ray imaging

## Overview of medical imaging procedures

Medical imaging procedures utilise either ionising or non-ionising radiation. Non-ionising radiation is generally used in magnetic resonance imaging (MRI) and ultrasound (US) scans. Medical X-ray imaging refers to any medical examination that uses X-rays to produce images of human tissue. Typical medical X-ray examinations are X-ray projection radiography (e.g., chest radiographs, dental radiography, mammography), computed tomography (CT) scans, fluoroscopy and similar procedures in X-ray imaging prior to radiation therapy procedures.

Medical imaging procedures in diagnostic radiology involving ionising radiation are hereafter described.

### RADIOGRAPHY

X-ray radiographs are the most common X-ray imaging procedure. Radiographs are two-dimensional images acquired within a very short time, less than a second, that can depict any part of the human anatomy, including the skull, joints, limbs, chest, abdomen and pelvis. Radiographs are general purpose examinations that can be used, for example, to detect or diagnose infections, fractures, tumours and calcification. The radiation dose resulting from such procedures is very low.

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## FLUOROSCOPY

Fluoroscopic procedures use X-rays to produce real-time, continuous series of two-dimensional images of human tissues. Fluoroscopic procedures can last more than 10 minutes and are often used with an administered contrast. Fluoroscopy is typically used to diagnose functional problems, such as bowel functionality or blood flow (angiography). Interventional procedures are done to diagnose and treat the patient, an example of this is cardiac catheterization. Fluoroscopy can deliver relatively higher doses compared to other X-ray imaging examinations because of the required long exposure times.

## COMPUTED TOMOGRAPHY

Computed tomography (CT) scans use X rays to produce cross-sectional 3D images of human anatomy. The X-ray tube rotates around the patient to produce images of a specified anatomical area. Although CT scans account for a small percentage of all X-ray imaging examinations, they are a valuable tool in the diagnosis of many diseases, lesions, abnormalities and infections. CT scans can deliver radiation doses far larger than chest X-rays, but the information they provide is considerably superior to plain radiography or fluoroscopy.

## IMAGING IN RADIATION THERAPY

X-ray imaging has multiple applications in radiation therapy as well. CT scans are a standard procedure to determine radiotherapy treatment plans and allow for advanced highly conformal delivery techniques. During radiotherapy treatment, a patient can be accurately positioned using X-ray cone-beam computed tomography (CBCT), and X-ray fluoroscopy can be used during treatment delivery to detect patient motion and adapt treatments. The dose delivered prior or during radiation therapy from imaging procedures depends on the type of X-ray imaging procedure. Consecutive X-ray imaging examinations during multiple sessions of radiotherapy can increase the dose burden from imaging procedures, but it is nevertheless much lower than the treatment dose.

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# Radiation protection concepts and principles

Justification and optimisation are the two fundamental principles of radiation protection in medical exposure. Medical exposures are justified by weighing the expected diagnostic or therapeutic benefits against the potential radiation detriment, taking account of the benefits and risks of available alternative techniques that do not involve radiation exposure.

The latest advances in imaging technologies provide many benefits for acquisition and post-processing of image information. Measures can often be taken through optimisation of procedures, protocols and utilised parameters to reduce the radiation dose received without adversely affecting the diagnostic benefit of the examination.

# Radiation risks of medical imaging

## HEALTH EFFECTS OF RADIATION EXPOSURE

The magnitude of lifetime risks from ionising radiation depends on the radiation doses received. At low dose levels, the effects of ionising radiation may involve increased chances of leukemia, cancer and genetic defects. These effects are statistical in nature, known as stochastic effects. Deterministic effects, or non-stochastic health effects, are health effects related directly to the absorbed radiation dose, and the severity of the effect increases as the dose increases. Low radiation dose levels delivered during diagnostic procedures should not cause deterministic effects. Prolonged image-guided interventional procedures may, however, deliver doses high enough to cause tissue reactions such as skin erythema in some patients.

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Everyone has a non-zero chance of developing or dying from cancer over the course of a lifetime. This is the so-called lifetime baseline risk (LBR). Development of cancer is defined as the incidence, while cancer deaths are known as the mortality. The additional risk of premature incidence or mortality from a cancer attributable to radiation exposure is called the lifetime attributable risk (LAR). The LAR is an age- and sex-dependent risk quantity calculated using risk models derived from epidemiological studies.

According to studies for cancer risks, an overall lifetime risk of 28% is attributed for developing an invasive cancer. These statistics do not take into consideration individual risk factors from lifestyle choices such as smoking, diet and exercise; family history, for example, genetics; or radiation exposure. For patients who receive equivalent organ doses of 10 mSv, a common result of chest CT, excess risk is predicted to be 0.01%.

## COMMUNICATING RADIATION RISKS

Information strategies for radiation risk communication between the healthcare provider and patient should be comprehensive in order to address any valid concerns that may arise. In emergency situations, although there may not be time to obtain consent because of medical necessity, important explanations and information are usually provided regarding the procedure, doses and associated risks. On the other hand, when requesting imaging, communication between healthcare professionals includes referrals and appropriate guidelines. Such discussion is essential to establish safe patient pathways, especially when the urgency of immediate care prevents in-depth discussion.

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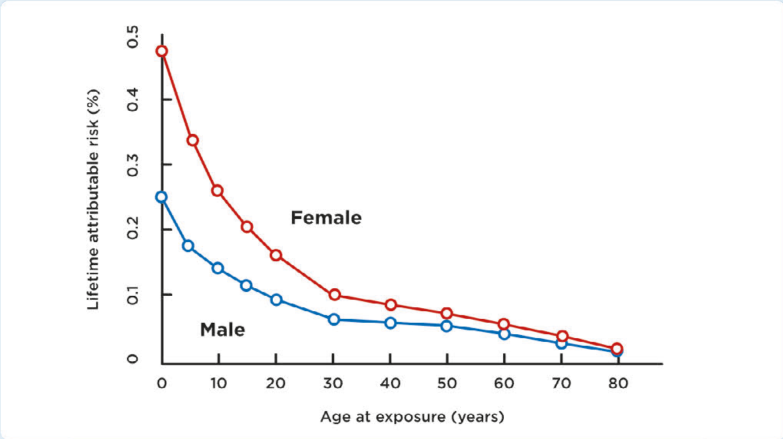
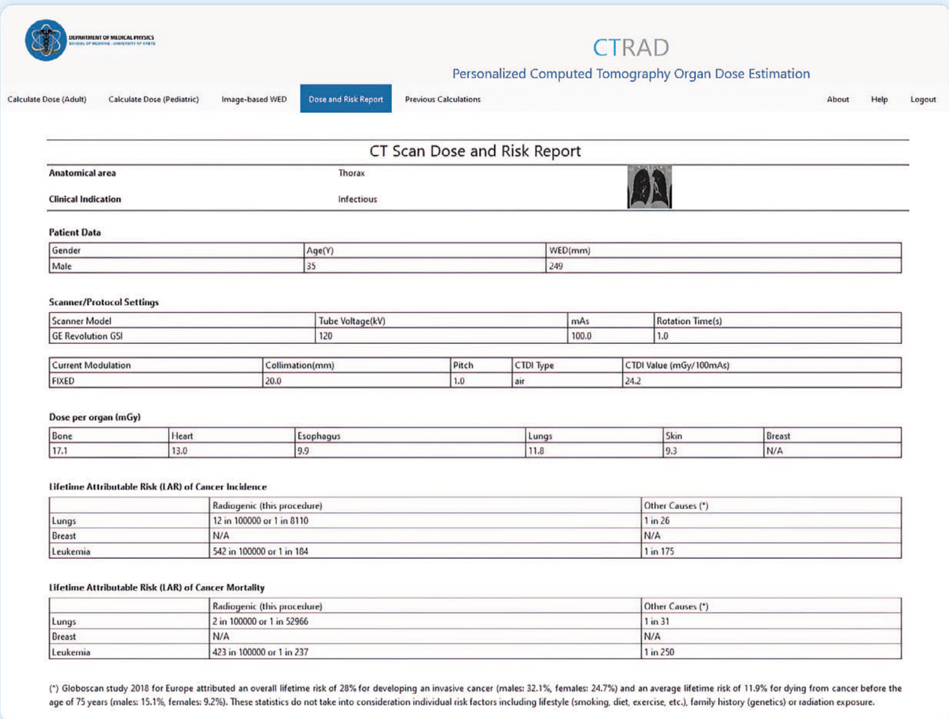



Lifetime attributable risk of cancer incidence as a function of sex and age at exposure for a single body exposure at a dose of 10 mSv, BEIR VII model (excess relative risk and excess absolute risk)




CT Scan Dose and Risk Report

| | |
|---|---|
| **Anatomical area** | Thorax |
| **Clinical Indication** | Infectious |

**Patient Data**

| Gender | Age(Y) | WED(mm) |
|---|---|---|
| Male | 35 | 249 |

**Scanner/Protocol Settings**

| Scanner Model | Tube Voltage(kV) | mAs | Rotation Time(s) |
|---|---|---|---|
| GE Revolution GSI | 120 | 100.0 | 1.0 |

| Current Modulation | Collimation(mm) | Pitch | CTDI Type | CTDI Value (mGy/100mAs) |
|---|---|---|---|---|
| FIXED | 20.0 | 1.0 | air | 24.2 |

**Dose per organ (mGy)**

| Bone | Heart | Esophagus | Lungs | Skin | Breast |
|---|---|---|---|---|---|
| 17.1 | 13.0 | 9.9 | 11.8 | 9.3 | N/A |

**Lifetime Attributable Risk (LAR) of Cancer Incidence**

| | Radiogenic (this procedure) | Other Causes (*) |
|---|---|---|
| Lungs | 12 in 100000 or 1 in 8110 | 1 in 26 |
| Breast | N/A | N/A |
| Leukemia | 542 in 100000 or 1 in 184 | 1 in 175 |

**Lifetime Attributable Risk (LAR) of Cancer Mortality**

| | Radiogenic (this procedure) | Other Causes (*) |
|---|---|---|
| Lungs | 2 in 100000 or 1 in 52966 | 1 in 31 |
| Breast | N/A | N/A |
| Leukemia | 423 in 100000 or 1 in 237 | 1 in 250 |

(*) Globoscan study 2018 for Europe attributed an overall lifetime risk of 28% for developing an invasive cancer (males: 32.1%, females: 24.7%) and an average lifetime risk of 11.9% for dying from cancer before the age of 75 years (males: 15.1%, females: 9.2%). These statistics do not take into consideration individual risk factors including lifestyle (smoking, diet, exercise, etc.), family history (genetics) or radiation exposure.

Screenshot of personalised CT organ dose estimation software (CTRAD) developed by UoC (http://ctdose-iqurad.med.uoc.gr/ctrad), depicting lifetime attributable risks of cancer incidence and mortality using estimated exposed organ doses and biological effects of ionising radiation, (BEIR) VII model (excess relative risk and excess absolute risk)

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