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Software tool (CT-IQURAD) module on radiation dose

Lead partner:	University of Crete (UoC)
Author(s):	John Stratakis, Marios Myronakis, John Damilakis
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1. Introduction

Radiation risk to human health has been the subject of continuous research and debate for many years. Radiation exposure associated to computed tomography (CT) examinations has been identified as a major source of medical radiation burden for adult and pediatric subjects [1, 2]. Attention has been emphasized on children as they are often considered to be more vulnerable to radiation due to their increased radio sensitivity and longer life span expectancy [3]. To assess stochastic radiogenic risks resulting from a CT examination, the dose to specific radiosensitive organs should be estimated [4].

The primary objective of MEDIRAD task 2.1.2 was to propose a method for the accurate estimation of dose to primarily irradiated organ structures (bones, esophagus, breast (female), heart, lungs, skin) in pediatric and adult CT examinations by considering patient size, automatic tube current modulation and specific CT-scanner characteristics with the use of patient-specific computational models. Potential end-users may include the medical physics, radiology and radiation epidemiology communities as well as radiologists, referring physicians and researchers.

The proposed method for scanner-specific and patient-specific, organ-dose estimation and optimization, is based on a procedure that combines Monte Carlo computational techniques and patient CT scans. In general, the procedure is composed of five steps, detailed in subsequent paragraphs; (a) collection of suitable patient CT scans; (b) determination of scanner parameters; (c) Monte Carlo (MC) dosimetric computations; (d) three-dimensional (3D) patient-specific dose distribution output and (e) correlation between dose and patient characteristics. These five steps need to be performed only once for each CT scanner. Thereafter, the results obtained at step (e), i.e., the correlation between organ-dose and patient characteristics, is used to calculate organ doses for subsequent patients that undergo chest CT scans.

2. Monte Carlo (MC) dosimetric computations

The MC software selected for dosimetric computations was the ImpactMC package (version 1.6, CT Imaging© GmbH, Erlangen, Germany). ImpactMC is a software package providing fast calculation of 3D dose distributions for computed tomography (CT) scans using Monte Carlo algorithms. ImpactMC is a well validated MC software, specifically designed for 3D dosimetric evaluation on CT acquired images [5-8]. Based on the CT volumetric data as input, an individualized voxelized Monte Carlo simulation is performed to calculate the dose deposited. Dose is calculated on a per image voxel basis, considering all available physical interactions.

ImpactMC's output comprises of parametric dose images in which every voxel carries the normalized dose (to CTDI) of the initial image grid. The generated 3D dose distributions are useful to estimate organ doses and to calculate effective dose of individual scans. ImpactMC utilizes any available Nvidia graphics processing unit (GPU) to accelerate computations. Specifically, it makes use of any CUDA-enabled GPU, employing NVIDIA's parallel computing platform and application programming interface (API) model [9]. The following input data were required by the software to start the dose computation procedure:

1. Input volume: The input volume represents the scanned patient or phantom; a set of CT reconstructed images from one examination, in DICOM format. In the current work the input volume is each patient (pediatric or adult) thorax CT.
2. Scan parameters: Data for beam spectrum, filtration and geometrical specifications.
3. Simulation parameters: The number of x-rays depositing energy in the input volume was selected. Good statistical performance (<1% uncertainty) was obtained using a value in the order of 10^8 to 10^9 interacting x-rays.

Scanner-specific dose computations required the parameterization of the Monte Carlo software according to operating and physical characteristics of each scanner considered. CT scanner models were based on data for x-ray beam spectra, beam shaping devices (bow-tie filters) and geometrical specifications.

Patient CT scans were used as input volumes to perform dosimetric computations in ImpactMC. Pediatric cases were simulated for 80, 100, and 120 kV for each scanner. Adult cases were simulated for 80, 100, 120, and 140 kV. A subset of the collected CT scans was acquired using tube current modulation. Two simulations were performed for each model: (i) a simulation with a Fixed Tube Current (FTC) value and (ii) a simulation with the ATCM system activated. In the first simulation, the mA was kept constant in all tube rotations throughout the entire examination length. In the second simulation, a different mA value was applied for each individual tube rotation.

The Monte Carlo software output after each computation was in the form of a 3D dose distribution, based on the physical properties (i.e. attenuation, composition and size) obtained from the input CT scan. Each slice in the dose volume corresponds to the same slice in the CT scan. Each pixel in a specific slice of the CT volume has a corresponding dose value in the 3D dose distribution output. The dose distribution was exported in DICOM file format. To facilitate dose data processing, the output dose was normalized to CT dose index in free air (CTDIair) and CTDIvol. The unit of dose values in the 3D volume was mGy/mGy per 100mAs.

3. 3D-based organ dose estimation

Organ dose information was extracted from 3D dose distributions through appropriate delineation. The tissues of interest in this work were bones, lungs, esophagus, breast, heart and the skin. The contours of an organ were overlaid on the corresponding slices of the dose distribution and the respective dose was extracted. The dose over the whole organ was computed as:

$$D = \sum_{i}^{N} D_i \qquad (1)$$

where, D_i is the dose within the contour at slice i, and N the total number of slices that contain contours of a specific organ. The calculated dose (D) was normalized to 100 mA, pitch factor (p) equal to one, and rotation time (t_{rot}) equal to one second using the following formula:

$$D_n = D \times \frac{p100}{t_{rot} \times mA} \qquad (2)$$

4. Water-equivalent diameter (WED) and correlation between dose and patient characteristics

Water equivalent diameter (WED) is an attenuation-based size metric that may be used to quantify patient size in CT [10]. The WED size metric proposes the diameter of a hypothetical cylindrical water phantom that has the same average attenuation as the body region being examined. AAPM TG220 recommended the adoption of water equivalent diameter (WED or Dw) as the preferred patient size metric for accurate size-specific dose estimates (SSDE) from CT scanning. WED calculation is performed on axial CT image slices and is based on the CT number, i.e. Hounsfield Units (HU), of the imaged patients using the following formula:

$$WED = 2 \times \sqrt{\left[\frac{1}{100}\overline{CT(x,y)_{ROI}} + 1\right] \times \frac{A_{ROI}}{\pi}} \qquad (3)$$

where $\overline{CT(x,y)_{ROI}}$ is the average HU value over each x, y location in the ROI that contains the imaged patient in one slice. A_{ROI} is the area of the ROI. WED can also be calculated on localizer (scout) images but yields less accurate results [10].

Accurate WED determination requires detailed delineation of the patient body outline on the CT slice without including the CT couch/table. In radiation therapy, body, organ and tissue delineation is part of the treatment planning routine, hence, body outline is readily available.

In diagnostic radiology, such delineations are not usually provided. Although this task can be performed manually by experts, it is practically cumbersome and time-consuming over a large number of patient CT scans.

WED and organ dose correlation was determined through univariate regression analysis. The estimated regression function was of the exponential form

$$y = a \cdot e^{b \cdot x} \qquad (2)$$

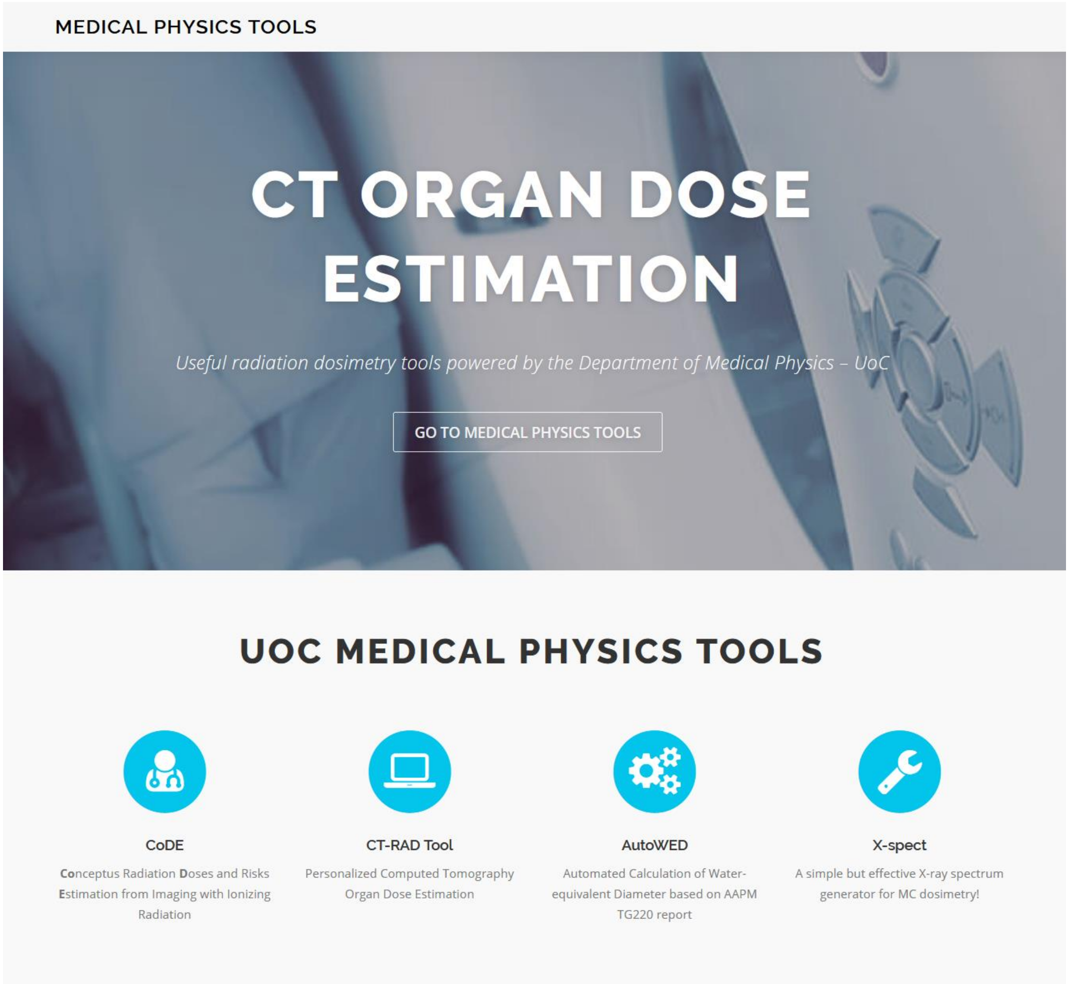
were the independent variable, x, corresponds to the WED value in millimeter (mm) units, estimated per patient as described previously. The WED was measured at the central axial plane crossing the geometrical center of the heart. The variable y, corresponds to the dependent variable, organ dose in mGy/mGy/100mAs (or similar normalized unit). Parameters a and b were estimated for each patient-specific WED at each organ dose computed by the Monte Carlo software. The coefficient of determination r^2, was used as a measure to assess the strength of correlation between WED and organ dose.

The proposed method has several advantages: 1) Patient models were used instead of phantoms and, therefore, results are based on true patient-specific dosimetry, 2) Strong correlations between normalized doses and patient WED ensure that highly accurate organ dose estimations are observed, and 3) the method is applicable to both adult and pediatric patients undergoing chest CT examinations. Finally, data produced allows the development of a web-based tool (CTRAD) capable of estimating organ radiation doses quickly and accurately.

5. Software development – CTRAD web calculation tool

The server-side (backend) of the calculation tool was developed using Python Django. The client-side (frontend) was implemented using HTML5, pure JavaScript, jQuery, AJAX JavaScript libraries, and Bootstrap for the CSS. jQuery is a JavaScript library designed to simplify HTML DOM tree traversal and manipulation, as well as event handling, CSS animation, and Ajax. Bootstrap is a free and open-source CSS framework directed at responsive, mobile-first front-end web development. It contains CSS- and optionally JavaScript-based design templates for forms, buttons, navigation, and other interface components. In addition, since XML was not suitable to handle all database entries and possible future data implementations, so MySQL was employed.

Personalized Computed Tomography Organ Dose Estimation Tool (Abbrev. **CTRAD**) is installed at http://medphys-tools.med.uoc.gr and is available upon free user registration (Figure 1, next page).



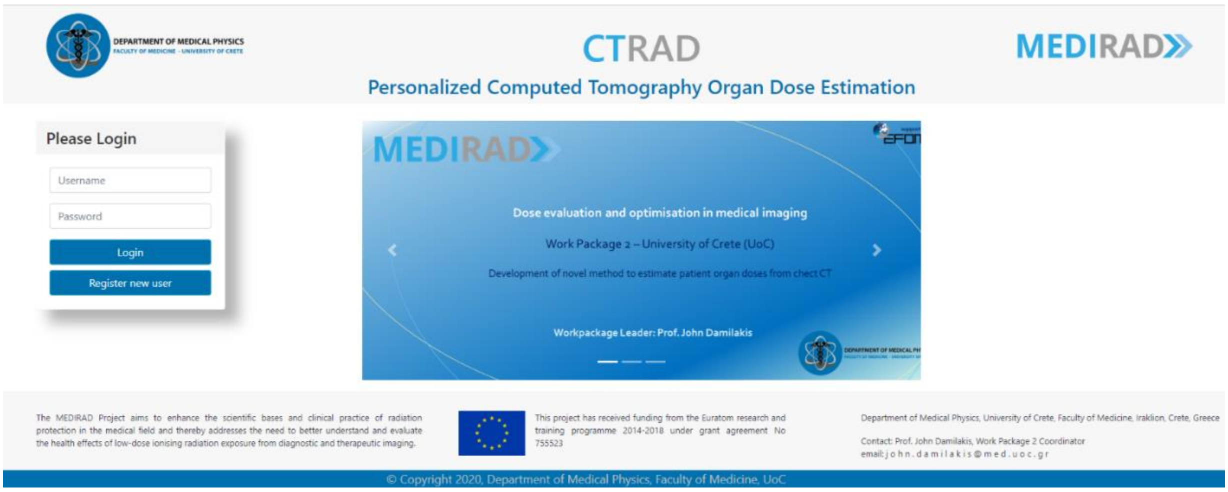


Figure 1:UoC Medical Physics tools web site and login page of CTRAD organ dose estimation tool, which is located at http://medphys-tools.uoc.gr

6. Automatic Imaged-Based Water-equivalent diameter (WED) calculation module

Accurate WED determination requires detailed delineation of the patient body outline on the CT slice without including the CT couch/table. Within CTRAD, an automatic module for calculation of WED based on user-uploaded CT scans was developed. The algorithm is based on morphological operations applied on each image slice. A square structuring element with heuristically determined size equal to 12 pixels was used to perform morphological opening. This step effectively removed small structures in the vicinity of the body and preserved the body shape and size. The next step was conversion of the image to binary using Otsu's method to determine the single HU threshold between background and any other structure [11, 12]. During this step, the couch is usually removed from the image without affecting the body size or shape. Lungs and other low-density tissues are likely to produce empty space (holes) in the binarized image within the region defined by the body shape. This empty space was filled by detection of zero value locations that were not connected with the image borders. In the final step, non-zero areas that were not connected were identified and the largest area was kept (i.e. the body) – this step was rarely required but nevertheless performed (Figure 2).

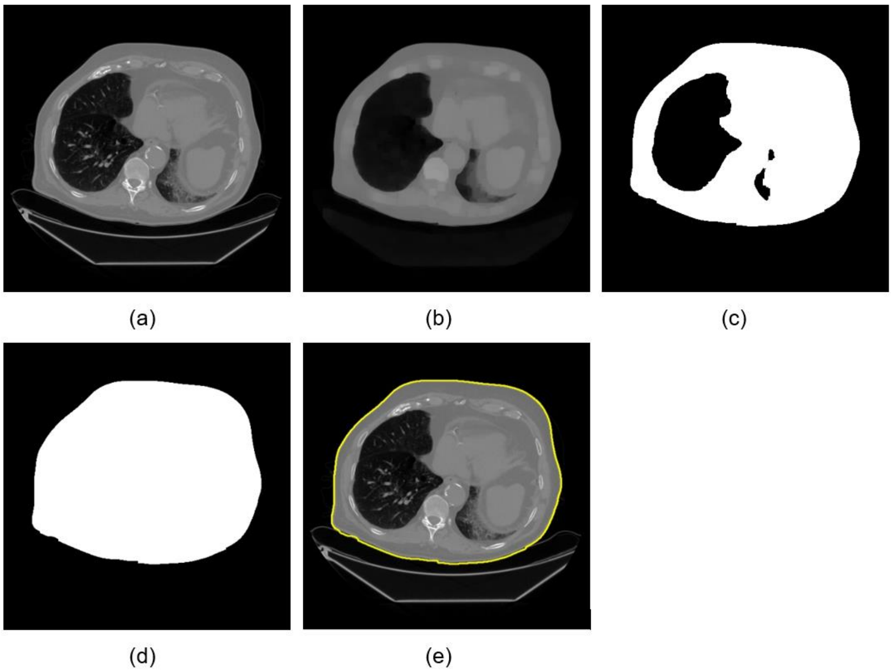


Figure 2: Step by step algorithm representation of automatic WED calculation module

For imaged-based WED calculation, the user is prompted with an interface to upload a single DICOM image or a DICOM series as a group of images for the WED calculation (of each image/slice) to AAPM TG220 formulation. No images and DICOM header information are stored after exiting the Imaged-Based calculation tab, so there is no risk of sharing sensitive patient data.

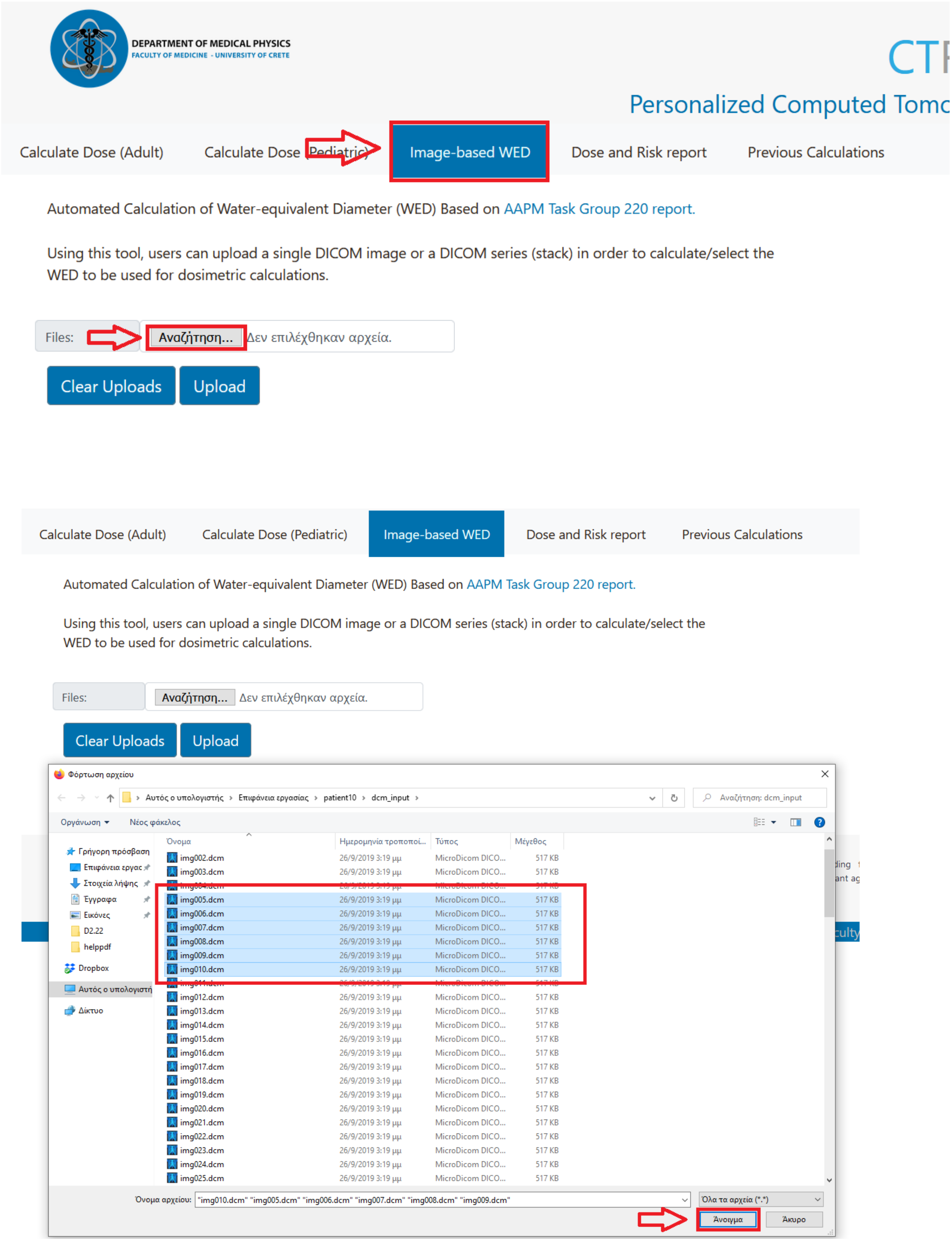


Figure 3: Image-based WED tool inside CTRAD organ dose calculation tool with user image upload capability

WED and tube current values for each uploaded DICOM image are presented and the user can select which WED value will be used/transferred in the organ dose calculation tab. Users can use average, median, or WED value for a specific slice in this tool (Figures 3,4).

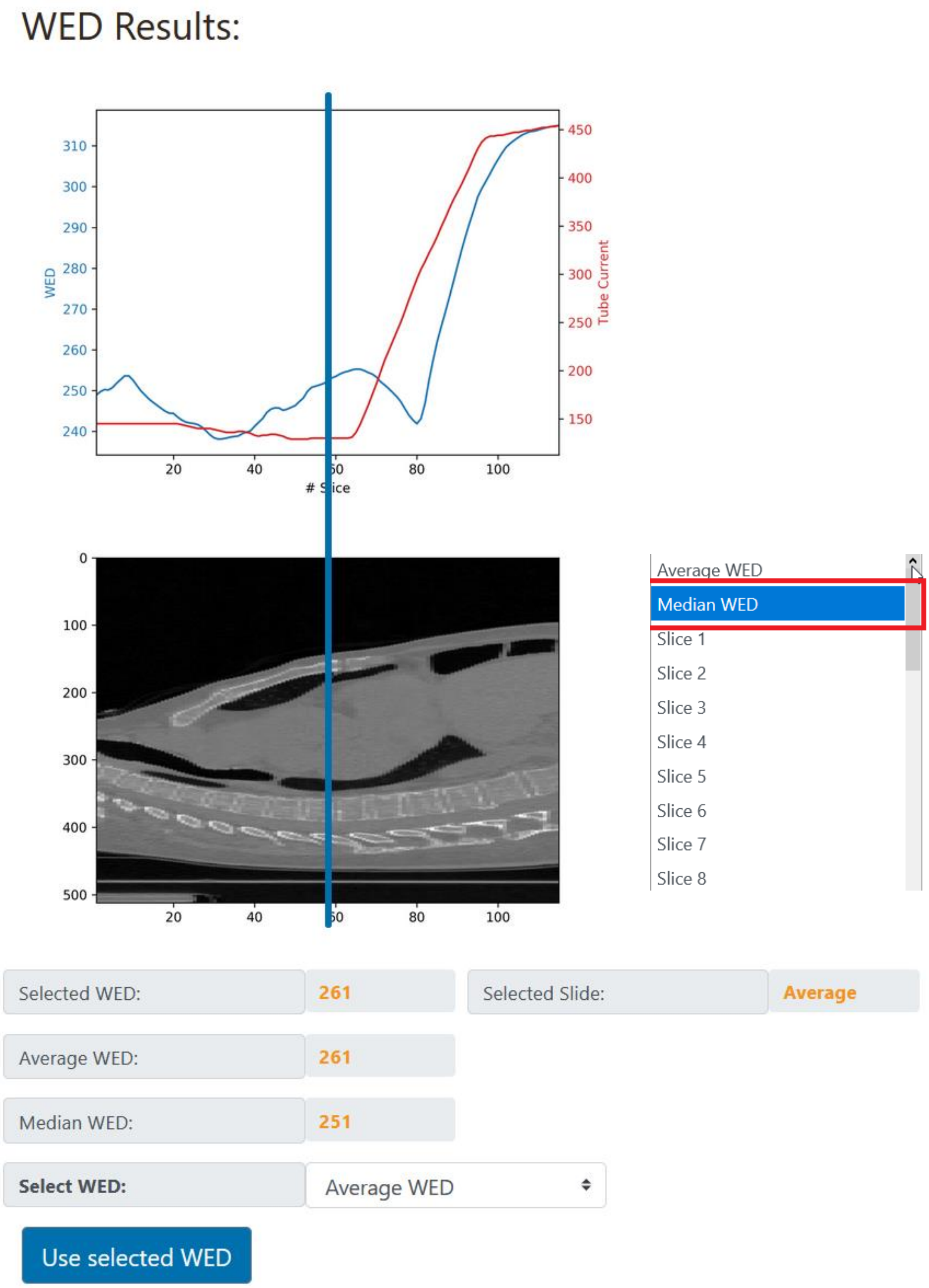


Figure 4: Image-based WED calculation from user-supplied DICOM series inside the CTRAD organ calculation tool

7. CTRAD web tool calculation interface

The web-tool dose calculation code is implemented using Javascript on the client side. This reduces load from server-side requests and improve dose calculation time and web-site responsiveness.

User input fields are organized into three groups:

- The ‘Patient Group’ requires basic demographic input (i.e., age and gender), CT scan region (currently thorax is the only available choice), and WED, which can either be directly inserted as a number or calculated using the automatic WED calculation tool.
- In the ‘Scanner Group’, users will select the CT scanner model (three models currently available) and corresponding exposure settings (i.e., kV, mA, current modulation, beam collimation, pitch, and rotation time). Users will also select the clinical indication for the CT scan.
- In the ‘CTDI Group’, users enter the CTDI type and value they for their corresponding scanner.

Each group can appear or disappear on the screen based on the preference of the user as an “accordion” implementation (Figure 5, next page).

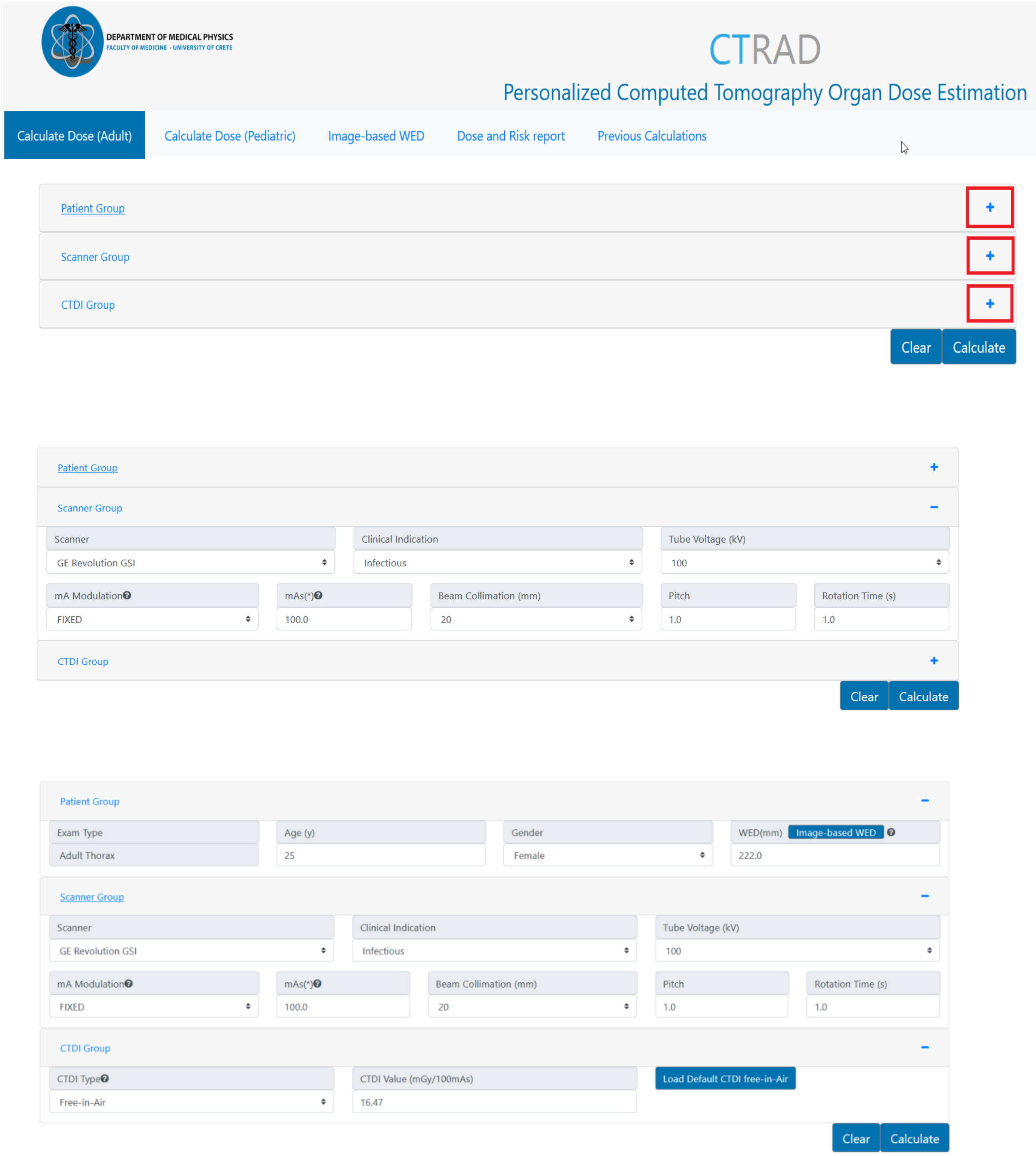


Figure 5: CTRAD web calculation tool interface accordion implementation overview

8. CTRAD interface – Adult Calculation tab

CTRAD adult calculation tab provides dose estimates for organs in the thorax region for adult patients undergoing chest CT examinations for various exposure settings (i.e., kV, mA, current modulation, beam collimation, pitch, and rotation time).

Patient Group submenu requires demographic data such as gender and age to be entered. This data is required for organ dosimetry and risk estimation. Water equivalent diameter is needed for correlation between absorbed organ dose and patient size characteristics. WED is given in millimeters and can be entered as a value or calculated from user-uploaded CT data utilizing the Image-based WEB tab (Figure 6).

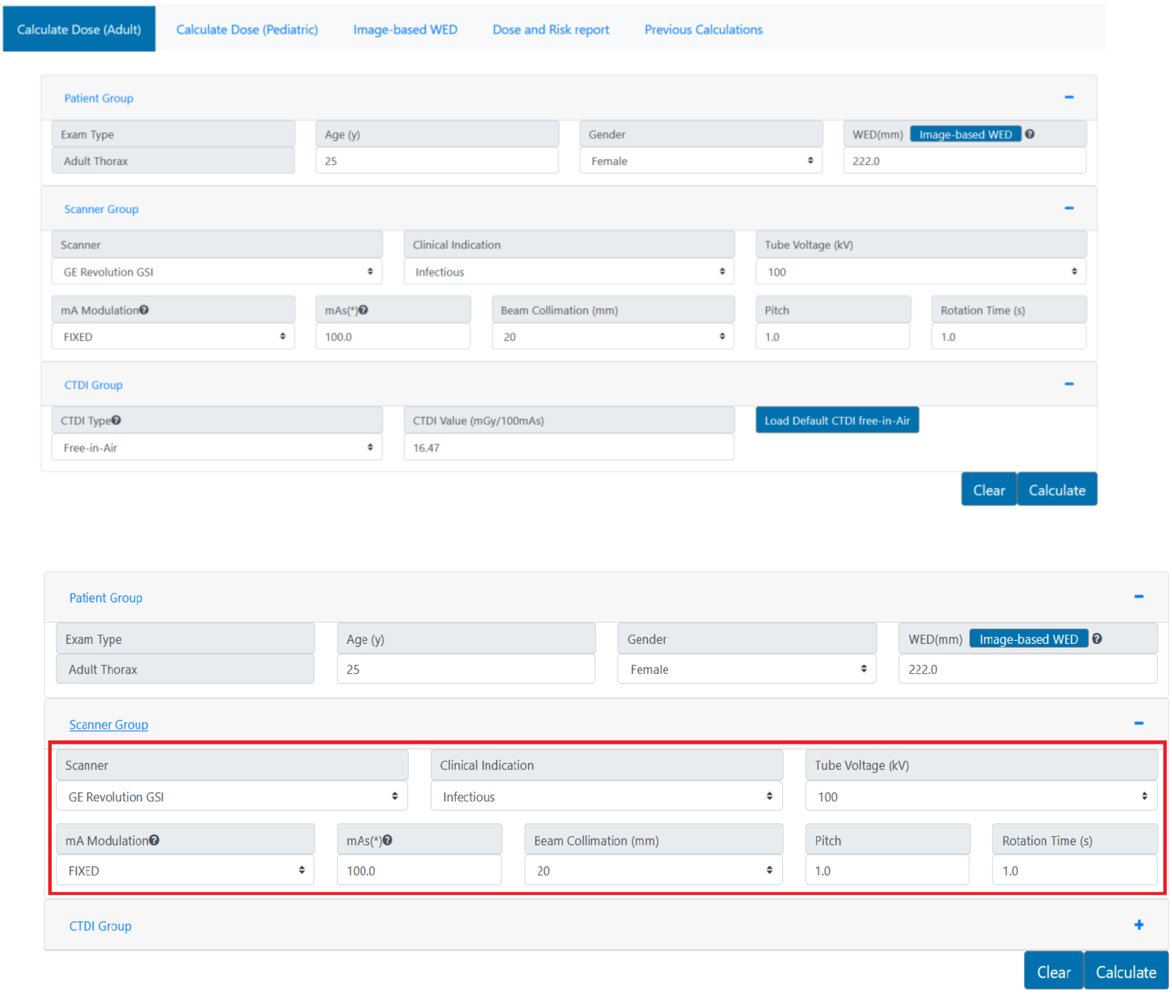


Figure 6: CTRAD organ dose calculation tool - main calculation tab - adults

Scanner Group submenu requires:

- Selection of CT scanner; Currently there 3 scanners available: Siemens Sensation 16 and 64 and GE Revolution.

- Clinical indication: User can select one of the three available clinical indication for patients undergoing thorax CT exams: Pulmonary fibrosis, infectious diseases, pulmonary metastases.
- Tube Voltage: A pull-down menu guides the user to enter the selected tube voltage for the CT scan; for adult examinations tube voltage can range from 80 to 140 kV.
- mA modulation: User can select if tube current modulation (TCM) or fixed tube current (FIXED) will be utilized or not for organ dose calculation.
- mAs: User can manually enter the mAs of the examination. For Siemens scanners, effective mAs reading from CT console should be used.
- Beam Collimation: Beam collimation in millimeters. In MDCT the actual beam collimation is not directly correlated with slice thickness. It is the length of the individual detector (or linked detector elements) acquiring data for each of the simultaneously acquired slices that limits the width of the x-ray beam contributing to that slice, this length is often referred to as detector collimation. Beam collimation depends on CT scanner and detectors configuration (Figure 7).

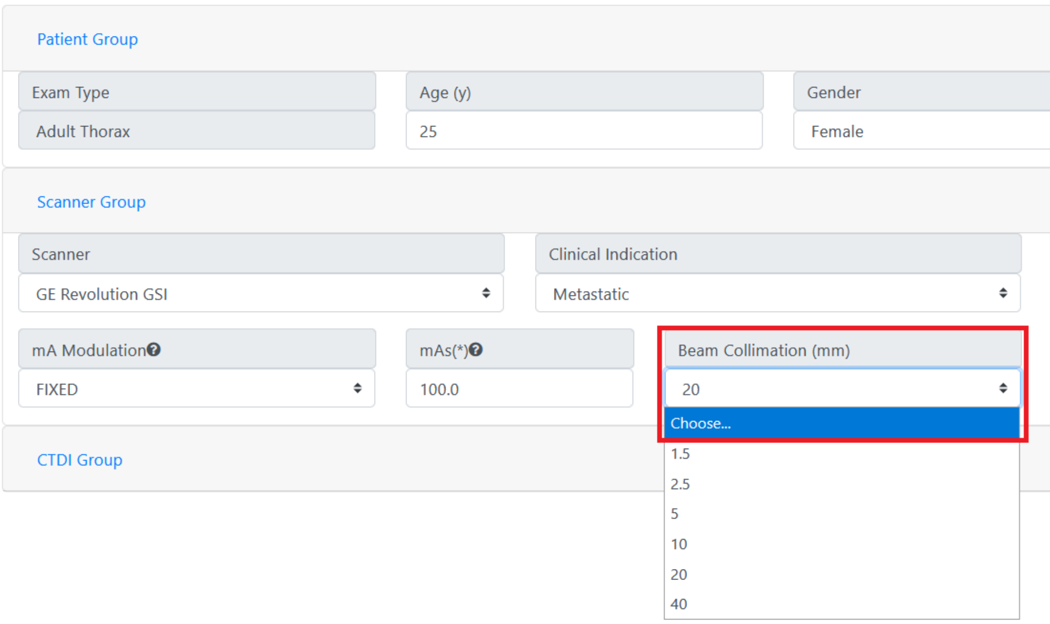


Figure 7: CTRAD organ dose calculation tool - scanner group tab - beam collimation selection menu

- Pitch: User can select pitch of the examination.
- Rotation time: User can specify time (in seconds) in which a full gantry rotation is performed.

CTDI Group submenu requires the user to enter CTDI type and value they for their corresponding scanner. CTDI values can be entered in CTDI-free-in-air for CTDI-vol form.

9. CTRAD interface – Pediatric Calculation tab

CTRAD adult calculation tab provides dose estimates for organs in the thorax region for pediatric patients undergoing chest CT examinations for various exposure settings (i.e., kV, mA, current modulation, beam collimation, pitch, and rotation time).

Patient Group submenu requires demographic data such as gender and age to be entered. This data is required for organ dosimetry and risk estimation. Water equivalent diameter is needed for correlation absorbed organ dose and patient size characteristics. WED is given in millimeters and can be entered as a value or calculated from user-uploaded CT data utilizing Image-based WEB tab (Figure 8, next page).

Scanner Group submenu (Figure 8) requires:

- Selection of CT scanner; Currently there 3 scanners available: Siemens Sensation 16/64 and GE Revolution.
- Tube Voltage: A pull-down menu guides the user to enter the selected tube voltage for the CT scan; for pediatric examinations tube voltage can range from 80 to 120 kV.
- mA modulation: User can select if tube current modulation (TCM) or fixed tube current (FIXED) will be utilized or not for organ dose calculation.
- mAs: User can manually enter the mAs of the examination. For Siemens scanners, effective mAs reading from CT console should be used.
- Beam Collimation: Beam collimation in millimeters. Beam collimation depends on CT scanner and detectors configuration.
- Pitch: User can select pitch of the examination.
- Rotation time: User can specify time (in seconds) in which a full gantry rotation is performed.

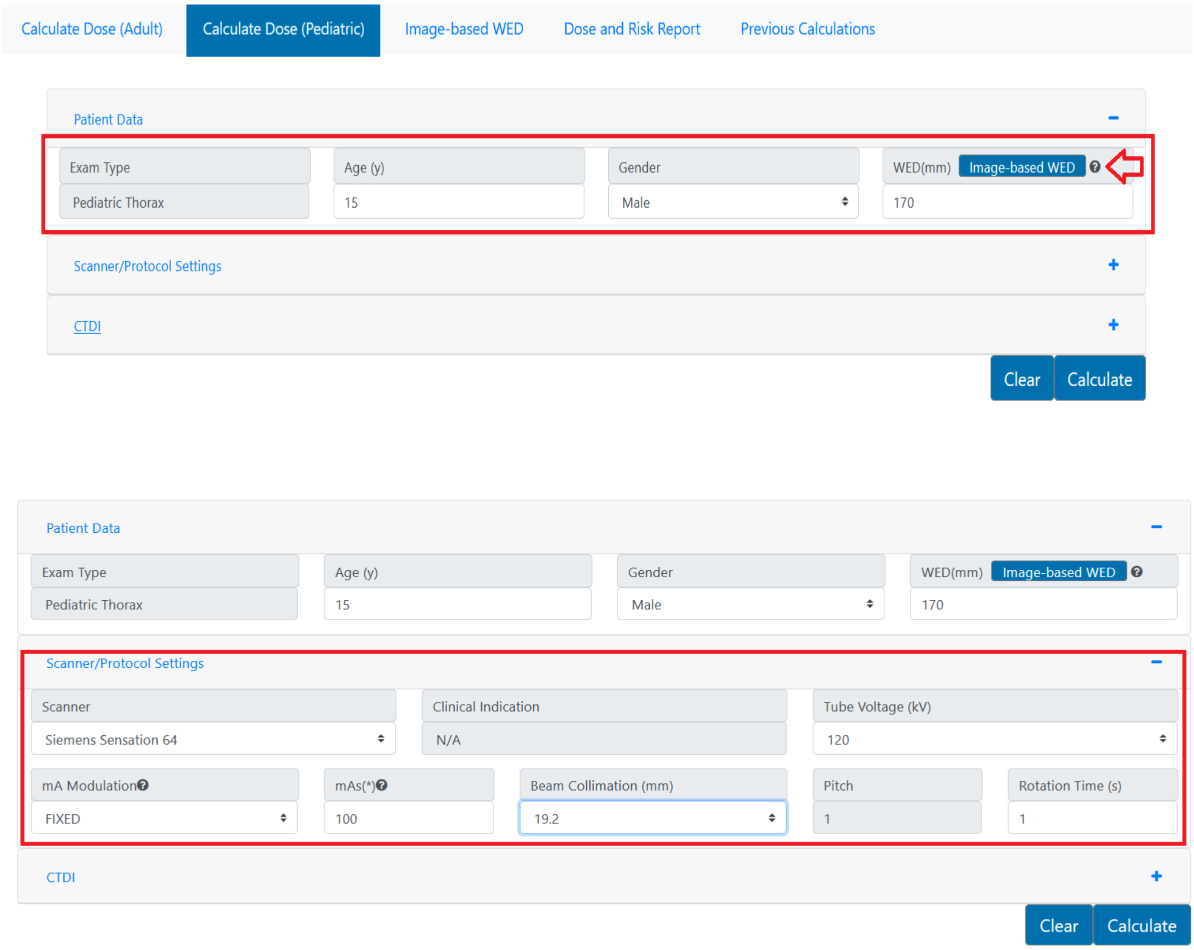


Figure 8: CTRAD organ dose calculation tool - main calculation tab - pediatric patients

10. CTRAD interface – Dose and Risk report tab

Calculated organ doses can be used for the assessment of the risk of exposure-induced cancer. The risk estimates are based on the combined absolute and relative risk models of BEIR VII committee [13]. The models consider the cancer site, sex, age at the exposure and attained age. Age-dependent mortality rates are used for subsequent assessment of lifetime cancer risk. Risk models are presented for leukemia and solid cancers in organs that radiation absorbed dose is provided. CTRAD calculates the risk of exposure-induced death (cancer mortality) for leukemia and solid cancer for those organs. Also, the user may use the risk calculation module for estimating the cancer risk (cancer incidence) resulting from a predefined single CT exposure (Figure 9).

Many factors, e.g., limitations in epidemiologic data for radiation-induced cancer, contribute to the uncertainty of risk estimation. The BEIR VII committee suggests that the risk estimates should be regarded with a healthy skepticism, placing more emphasis on the magnitude of the risk. The committee estimates that the excess cancer mortality due to radiation can be estimated within a factor of two (at 95% confidence level). For leukemia the corresponding factor is four. For individual solid cancer sites, the risk estimation may have large uncertainties, up to an order of magnitude or more. BEIR VII committee assumes that solid cancers have a latency period of 5 years. For leukemia the latency period is 2 years.

Dose per organ (mGy)

Bone	Heart	Esophagus	Lungs	Skin	Breast
22.1	11.9	10.6	10.9	12.9	N/A

LAR of cancer incidence

	Radiogenic (this procedure)		Other Causes
Lungs	20 in 100000	or 1 in 5097	1 in 26
Breast	N/A	N/A	N/A
Leukemia	805 in 100000	or 1 in 124	1 in 175

LAR of cancer mortality

	Radiogenic (this procedure)		Other Causes
Lungs	3 in 100000	or 1 in 33979	1 in 31
Breast	N/A	N/A	N/A
Leukemia	537 in 100000	or 1 in 186	1 in 250

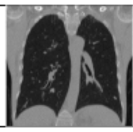
Figure 9: CTRAD organ dose calculation tool - Dose and risk report calculation tab

CTRAD software dose and risk report tab provides a summary of the absorbed dose per organ in mGy for each primarily irradiated thorax organ, as well as values of lifetime attributable risk for exposure-induced death (LAR for Lifetime cancer mortality) and lifetime attributable risk for cancer incidence (LAR for Lifetime cancer incidence) as shown in Figure 10. In addition to the radiogenic risks provided for the specific CT exposures, the software provides the corresponding LARs for cancer incidence and mortality for all causes (including radiogenic) as presented for the 40 countries in the four United Nations-defined areas of Europe and for Europe and the European Union [14].

CTRAD MEDIRAD

DEPARTMENT OF MEDICAL PHYSICS
FACULTY OF MEDICINE - UNIVERSITY OF CRETE

CT Scan Dose and Risk Report



Anatomical area	Thorax
Clinical Indication	Metastatic disease

Patient Data

Gender	Age (Y)	WED (mm)
Female	35	280

Scanner/Protocol Settings

Scanner Model	Tube Voltage (kV)	mAs	Rotation Time (s)
GE Revolution	120	100	1

Current Modulation	Collimation (mm)	Pitch	CTDI Type	CTDI Value (mGy/100 mAs)
fixed	20	1.0	FreeinAir	15.7

Dose per organ (mGy)

Bone	Heart	Esophagus	Lungs	Skin	Breast
9.2	7.2	5.6	6.3	5.3	6.4

Lifetime Attributable Risk (LAR) of Cancer Incidence

	Radiogenic (this procedure)	Other Causes (*)
Lungs	15 in 100000	1 in 6586
Breast	13 in 100000	1 in 20
Leukemia	217 in 100000	1 in 250

Lifetime Attributable Risk (LAR) of Cancer Mortality

	Radiogenic (this procedure)	Other Causes (*)
Lungs	13 in 100000	1 in 76
Breast	3 in 100000	1 in 71
Leukemia	179 in 100000	1 in 385

(*) 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.

Disclaimer: The aim of this report is to provide information about additional risk of cancer based on medical imaging, not to provide medical advice. Dose and risk calculations provided by the CT-RAD tool should be taken as estimates and may not be used solely for medical decisions. The benefits of justified medical imaging examinations almost always outweigh potential risks from ionizing radiation.

Figure 10: CTRAD Scan Dose and Risk Report example.

11. Verification of CTRAD and external evaluation

Organ doses for a specific male patient were estimated using a) the CTRAD tool, b) ImpactMC Monte Carlo software, and c) the National Cancer Institute dosimetry system for CT Version 3.0 [15]. The patient underwent a thorax CT examination with scan length equal to 310 mm.

CTRAD

The average WED was calculated from the reconstructed CT images using the Automatic Imaged-Based WED module described in §6 and was found equal to 286 mm. In addition, the average WED value was independently verified using ImageJ software. The exposure settings in CTRAD tool were set to 120 kV tube voltage, 100 mAs fixed tube current, 1 s rotation time and spiral pitch equal to 1. The clinical indication was metastatic. The $CTDI_{free\text{-}air}$ was set equal to 6.5 mGy for a Siemens SOMATOM Sensation 64 scanner and 28.8 mm beam collimation.

ImpactMC Monte Carlo Software

The chest CT acquisition was simulated with ImpactMC software using the same exposure settings as in CTRAD. The patient CT scan was imported in ImpactMC and 3D dose maps were generated. Organ contours for lungs, heart and esophagus were delineated and organ-specific dose values estimated.

NCI dosimetry system for CT

The NCI dosimetry system is based on the International Commission on Radiological Protection (ICRP) reference pediatric and adult phantoms. The calculated average WED for the ICRP reference adult male phantom within the scan range of a chest CT scan (Fig.11) was 286 mm which matched the average WED of the selected patient. The scanner information (including exposure settings) was the same as in CTRAD and ImpactMC software.

Verification metric

Organ-doses calculated with CTRAD and NCI dosimetry system were compared using relative differences (r) with organ-doses estimate with Monte Carlo (ImpactMC).

$$r(\%) = \frac{Dose_{calculated} - Dose_{MonteCarlo}}{Dose_{MonteCarlo}} \times 100$$

Results

Results are described in Table 1. Relative differences are shown within parentheses next to each dose value.

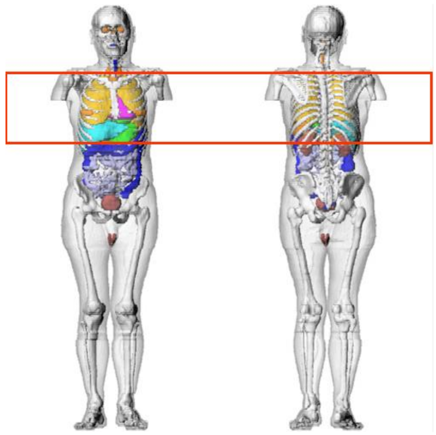


Figure 11: Chest CT scan-length in NCI dosimetry system

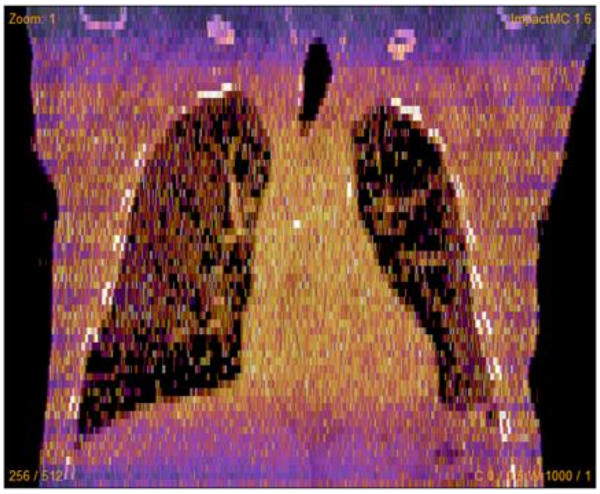


Figure 12: Dose output from ImpactMC software

There is very good agreement between CTRAD dose output and ImpactMC patient-specific and organ-specific dose estimation (Fig. 12). This was expected since CTRAD tool development was based on CT scans from (a) real patients with wide span of average WED values resembling attenuation of a variety of body types; (b) reference simulations on three different CT scanners; (c) three clinical indications for adult patients, and (d) measured or manufacturer supplied CTDIvol and CTDIair values for each reference scanner that were used to scale normalized doses to absolute.

Larger deviations were observed for NCI dosimetry system when compared to Monte Carlo derived doses. These were mainly attributed to (a) the exclusive use of anthropomorphic phantoms to derive organ-doses in NCI dosimetry system; (b) the sole use of one reference scanner (namely a Siemens SOMATOM Sensation 16); (c) the use of conversion factors to derive organ-doses for different scanner models, and (d) calculated rather than measured CTDIvol values for normalized dose scaling.

External evaluation

The CTRAD login details (userid and password) were provided to the University Hospital of Coimbra MEDIRAD team (contact person: Prof. Graciano Paolo) to evaluate the dose estimation tool. Coimbra team evaluated the usability, user interface and navigation, checked for possible software bugs and calculated doses and risks for several exposure scenarios for both paediatric and adult patients. An online meeting was organized to discuss the evaluation findings. In general, the Coimbra team is fully satisfied by CTRAD; this is a user-friendly web-based novel tool for equipment-specific, protocol-specific and patient-specific organ dose estimation. An additional useful feature is that CTRAD also supports reporting of radiation doses and associated radiogenic risks.

Table 1: Comparison between Monte Carlo estimated organ dose and CTRAD and NCI dosimetry system

	mGy		
Calculation Method	Esophagus	Heart	Lungs
Monte Carlo – ImpactMC	8.59	9.36	7.37
CTRAD	8.70 (1.2%)	10.3 (10%)	7.10 (-3%)
NCI dosimetry system	5.93 (-30.9%)	7.91 (-15.5%)	7.49 1.6%)

12. RESTful Web API for organ and risk calculation as a service

A RESTful API is an application interface for a website that allows two software programs to communicate with each other. The API spells out the proper way for a developer to write a program requesting services from an operating system or other application. A RESTful API -- also referred to as a RESTful web service or REST API -- is based on representational state transfer (REST), an architectural style and approach to communications often used in web services development. Application program interface (API) uses HTTP requests to GET, PUT, POST and DELETE data. CTRAD tool implements a set of REST service for an external application to authenticate and access the tool and perform dose and risk calculations without any GUI intervention.

Python3 and python3-pip must be installed for the script to work. A following python script (payload) example is given below:

```
import requests
import json

url = "http://ctdose-iqurad.med.uoc.gr:8000/api/token/"
payload = {
  'username': '$restuser$', # user credentials must be entered
  'password': '$rest password$' # user credentials must be entered
}
payload = json.dumps(payload)
headers = {
  'Content-Type': 'application/json'
}
response = requests.request("POST", url, headers=headers, data = payload)

data=json.loads(response.text)

url = "http://ctdose-iqurad.med.uoc.gr:8000/calculateDoseREST/"

payload = {
  "pediatric":"1", # 0 for adult calculation
  "age": "20",
  "sex": "1", # 1 for male, 2 for female
  "wed": "280",
  "scanner": "1", # 1 for GSI, 2 for Siemens 16, 3 for Siemens 64
```

```
 "clinicalIndication": "3", #1 for infectious, 2 for metastatic, 3 for pulmonary  # irrelevant for pediatric
 "tubeVoltage": "120",
 "current": "FIXED", # or AEC
 "mAs": "100",
 "beamCollimation": "40",
 "pitch": "1",
 "rt": "1", # rotation time
 "ctdit": "air", #or "vol"
 "ctdiv": "20",
}

headers = {
 'Authorization': 'Bearer ' + data["access"]
}

response = requests.request("POST", url, headers=headers, data=payload)

#data=json.loads(response.text)
#print(data)
print(response.text.encode('utf8'))
```

The payload consists of the values/flags for the remote organ dose/risk calculation presented in Table 1. Other scanners that will follow, shall have subsequent numbers (3, 4, etc).

Table 2: Values/flags for the REST organ dose/risk calculation

Payload parameter	**Value**
Exam type	1 for pediatric, 0 for adult calculation
Age	Age in years
(Patient) Sex	1 for male, 0 for female
WED	value in mm
Scanner	1 for GE Revolution, 2 for Siemens 16, 3 for Siemens 64*
ClinicalIndication	1,2,3 for infectious, metastatic and pulmonary, not accounted if pediatric exam type is selected
TubeVoltage	Value in kV
Current	FIXED for constant tube mA, AEC for ATCM
mAs	value in mAs
BeamCollimation	value in mm
pitch	Pitch in mm
rt	Rotation time in s

ctdit	CTDI type – air or vol
ctdiv	CTDI value in corresp. Values

13. Administration console of CTRAD software

CTRAD software implements a web-based administration console (provided that the user has elevated privileges to login as root) to manage user accounts, manually register new users, mass mail messages to registered users and update the dosimetric database with new coefficient data to enable calculations for further CT scanners and protocols. InFigure 13, part of the administration GUI is depicted, where the root user can manually edit information for each account. In addition, root user can delete, manually activate (if user failed or is unable to activate by email an already requested account) or suspend (deactivate) a user account.

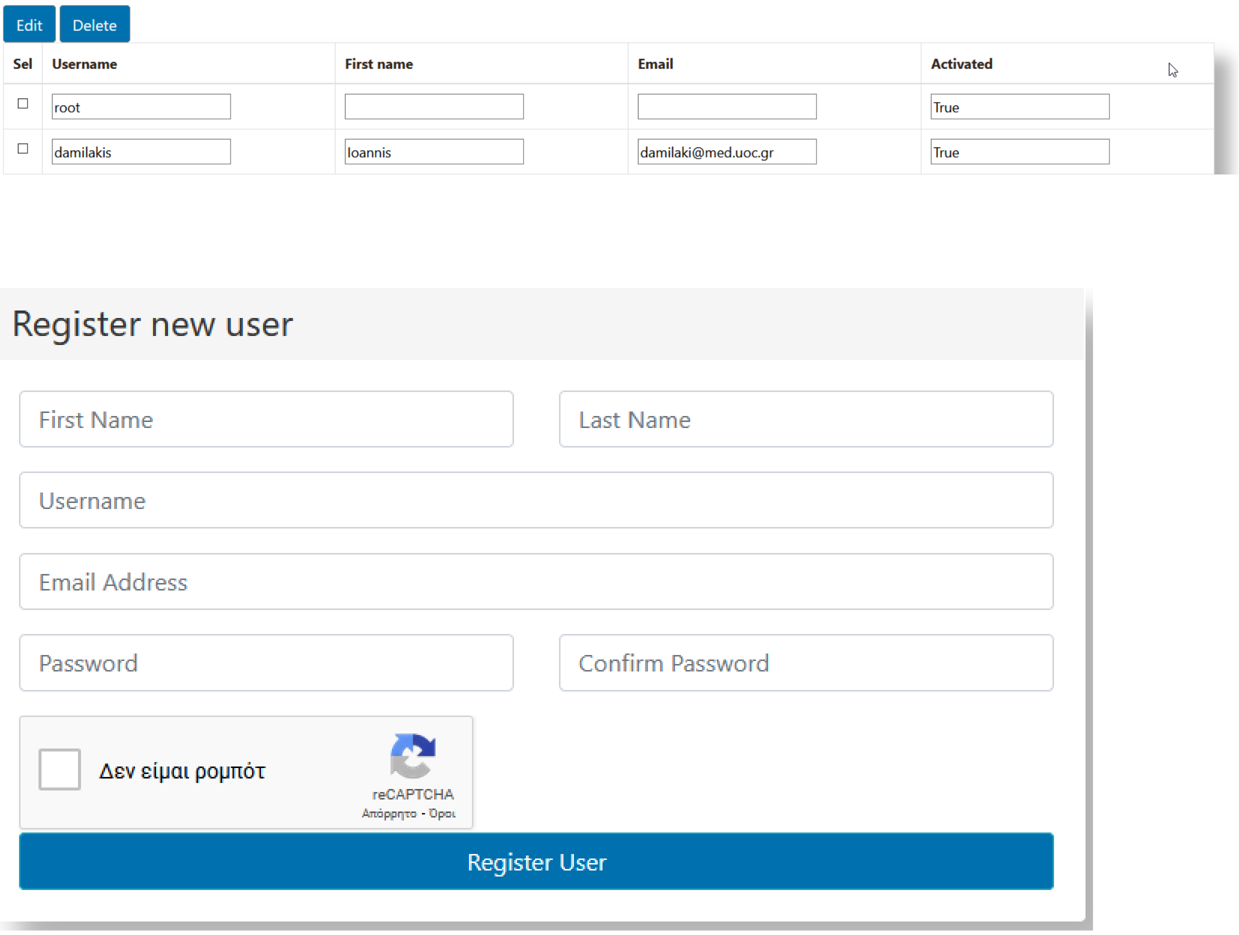


Figure 13: CTRAD administration console GUI - user manipulation.

Moreover, root (admin) user can send mail(s) to registered users, to inform them for changes in the platform (Figure 14). This eases administration of the software and enables users to access up-to-date information about the on-line calculation tool (eg. updates of the calculation coefficients database, bugs and errors correction, personal information alteration in the user database etc).

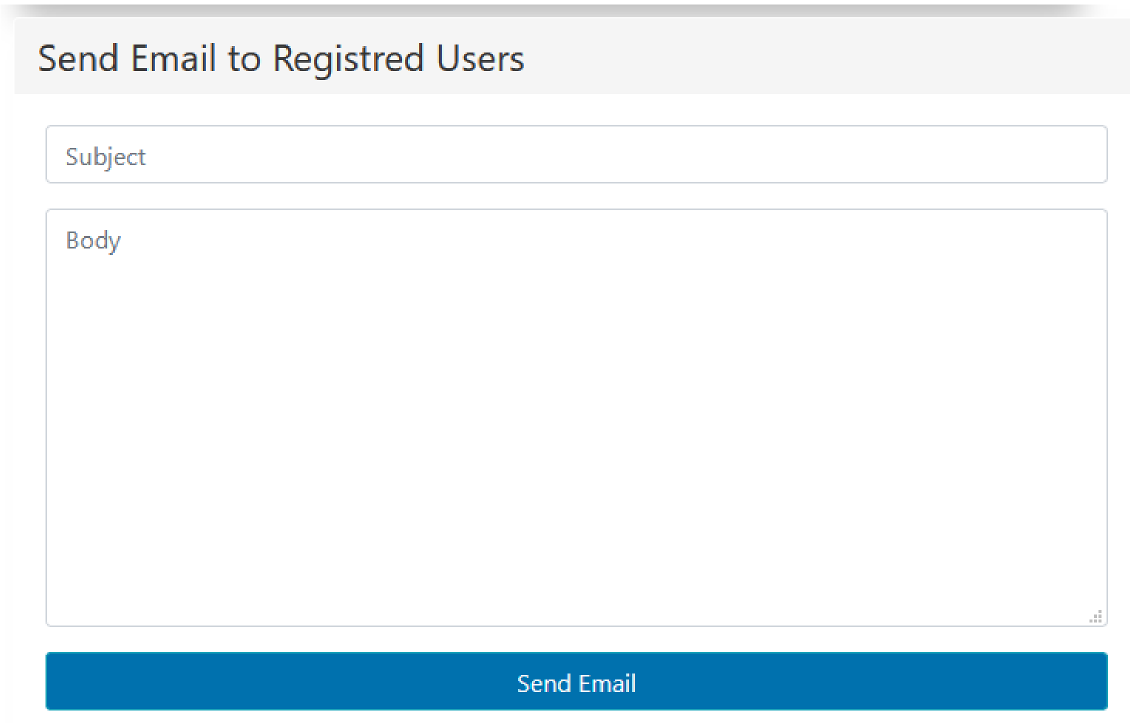


Figure 14: CTRAD administration console GUI - mass user mail tool.

Furthermore, root user can batch-update (Figure 15) the coefficient database in order to correct, update or append dosimetric coefficient data for further scanners, scan parameters and clinical indications by simply uploading csv files containing such data (eg Organ,Scanner,Indication,kV,AEC,a,b,R2).

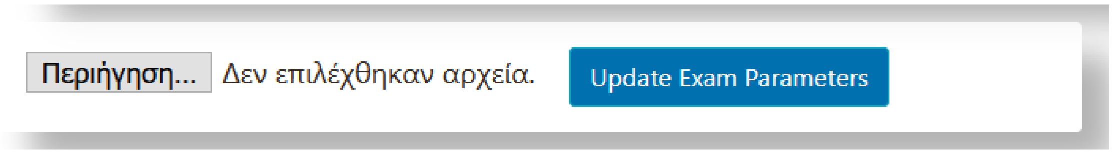


Figure 15: CTRAD administration console GUI - update exam parameters tool.

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