EPI-CT in Norway

EPI-CT: International **Epi**demiological Paediatric **CT** Study. Estimates on organ doses and ideas on optimisation in paediatric CT: Work in Norway

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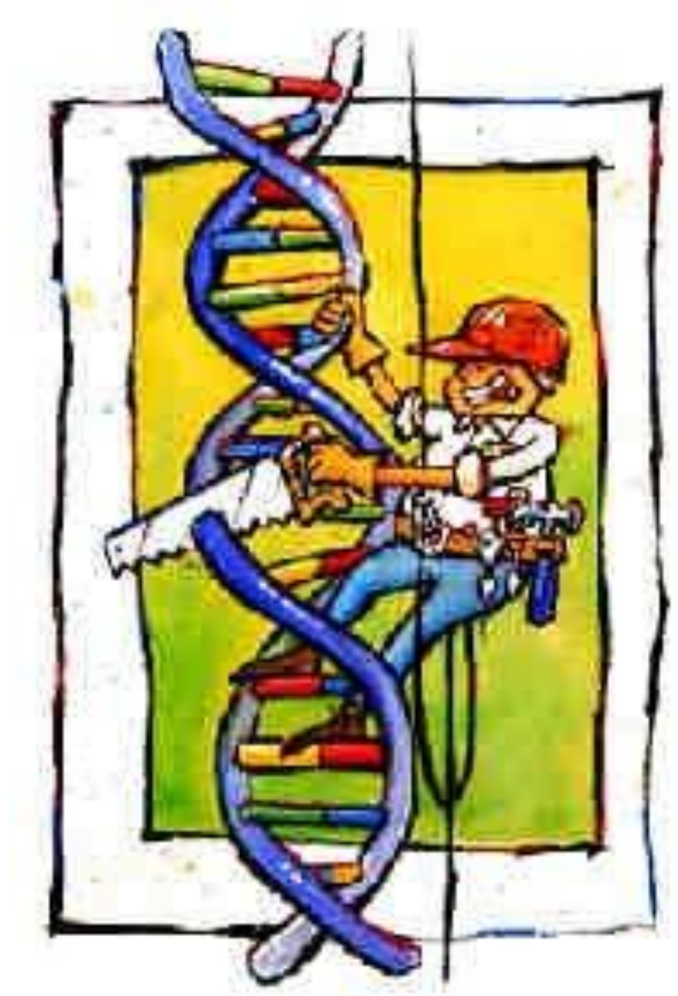
Statens strålevern

- Norwegian Radiation Protection Authority
- Established in 1993 - but history back to 1938
  - Merger of the National Nuclear Authority and the National Institute of Radiation Hygiene
  - Around 100 employees
  - Headquarters in Østerås, to the west of Oslo
  - Norwegian authority in radiation protection and nuclear safety
  - Monitors natural and artifical radiation

Statens strålevern
Norwegian Radiation Protection Authority

Er ioniserende stråling farlig?



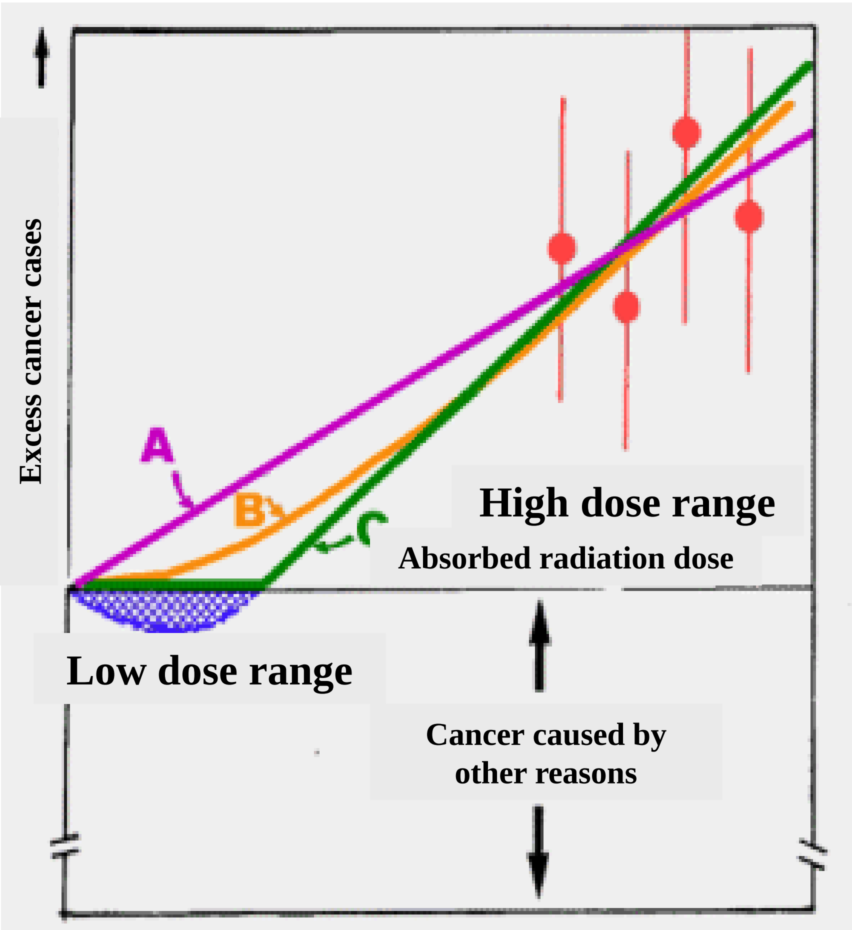
Deterministisk effekt

- Akutte skader på hud/organ/ celler som inntrer med sikkerhet over en viss terskeldose
- Graden av skade øker med økende dose

Stokastisk effekt

- Mutasjon i celler som fører til kreft og arvelige effekter
- Tilfeldig prosess, ingen terskeldose (?)
- Risikoen øker med økende dose

Is ionising radiation dangerous?



Deterministic effect

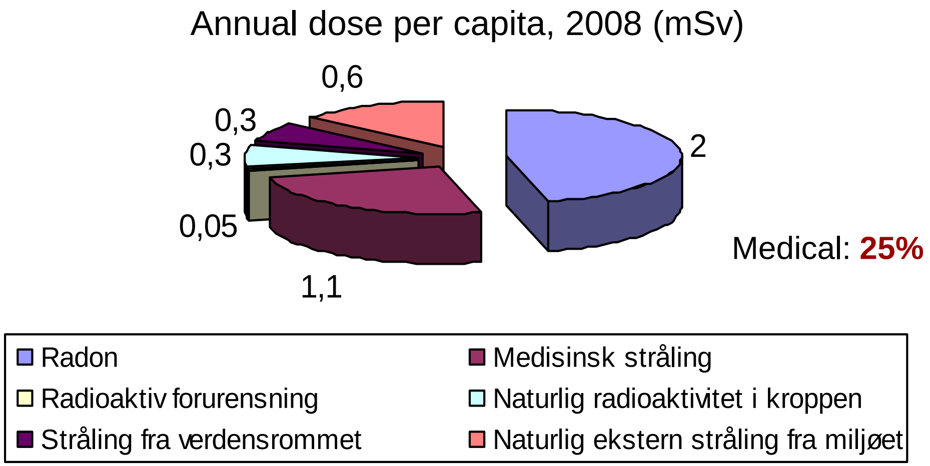
- Acute injuries occur over a certain threshold dose
- Degree of damage increases with dose

Stochastic effect

- Mutation in cells can lead to cancer and hereditary effects
- Random process, no threshold dose(?)
- Risk increases with increasing dose

Radiology in Norway in 2008

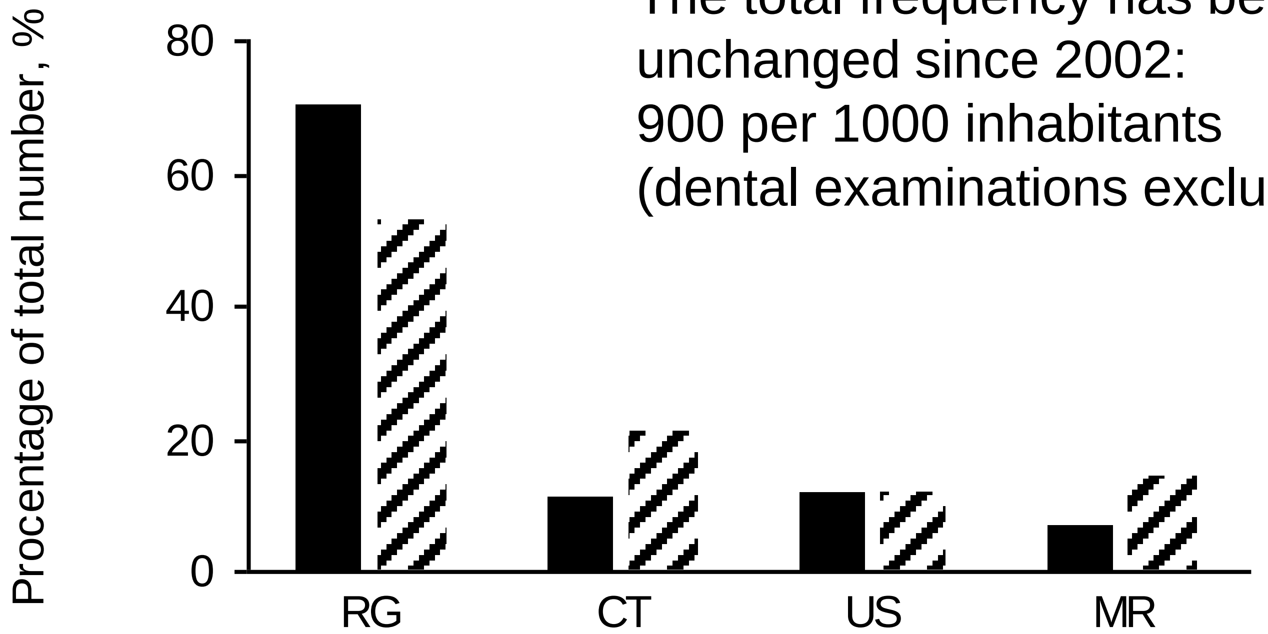
- 4.3 million studies
  - 0.9 studies per capita
- Population medical dose: 1,1 mSv/capita
- CT accounts for 80% of the population dose from radiology



Typical patient dose:
1-100 mSv

Trends in examination frequency

The total frequency has been unchanged since 2002:
900 per 1000 inhabitants
(dental examinations excluded)



	RG	CT	US	MR
2002	70	11	12	7
2008	53	21	12	14

- RG decreasing, CT and MR doubled, US stable

Why CT? Why children?

http://rileychildrenshospital.com/parents-and-patients/programs-and-services/radiology/ct-scan.jsp

CT:

- High dose for diagnostic x-ray
  - Organ dose: ~ 50-100 mSv
- High dose rate
  - DNA-damage/faulty repair?

Children:

- Radiation-sensitive individuals
  - Higher rate of cell division
- Longer life-expectancy
  - Long latency period
- Repeated studies
  - High accumulated dose

European project: EPI-CT

- Initiator: International Agency for Research on Cancer (IARC)
- Aims: Epidemiological study to quantify cancer risk from paediatric CT; dose optimisation
  - Multinational cohort
- Participants: 18 institutions from 11 countries
- Duration: 5 years
  - Started: 01.01.2011
  - Ending: 31.12.2015
- Premise:
  - Approval from ethical committees – ☺

European project: EPI-CT

- **11 countries contributing to the project:**
  - France**
  - Germany
  - Finland
  - Sweden**
  - United Kingdom** *(University of Newcastle-upon-Tyne)*
  - Spain
  - Denmark
  - Netherlands
  - Belgium
  - Luxembourg
  - Norway *(Norwegian Radiation Protection Authority* and *Cancer Registry Norway)*

** *Studies underway before EPI-CT project commenced*

Source: http://epi-ct.iarc.fr/consortium/index.php

UK contribution

THE LANCET

Lancet 2012;380:499-505

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

Mark S Pearce, Jane A Salotti, Mark P Little, Kieran McHugh, Choonsik Lee, Kwang Pyo Kim, Nicola L Howe, Cecile M Ronckers, Preetha Rajaraman, Sir Alan W Craft, Louise Parker, Amy Berrington de González

Summary

Background Although CT scans are very useful clinically, potential cancer risks exist from associated ionising radiation, in particular for children who are more radiosensitive than adults. We aimed to assess the excess risk of leukaemia and brain tumours after CT scans in a cohort of children and young adults.

Methods In our retrospective cohort study, we included patients without previous cancer diagnoses who were first examined with CT in National Health Service (NHS) centres in England, Wales, or Scotland (Great Britain) between 1985 and 2002, when they were younger than 22 years of age. We obtained data for cancer incidence, mortality, and loss to follow-up from the NHS Central Registry from Jan 1, 1985, to Dec 31, 2008. We estimated absorbed brain and red bone marrow doses per CT scan in mGy and assessed excess incidence of leukaemia and brain tumours cancer with Poisson relative risk models. To avoid inclusion of CT scans related to cancer diagnosis, follow-up for leukaemia began 2 years after the first CT and for brain tumours 5 years after the first CT.

Findings During follow-up, 74 of 178 604 patients were diagnosed with leukaemia and 135 of 176 587 patients were diagnosed with brain tumours. We noted a positive association between radiation dose from CT scans and leukaemia (excess relative risk [ERR] per mGy 0·036, 95% CI 0·005–0·120; p=0·0097) and brain tumours (0·023, 0·010–0·049; p<0·0001). Compared with patients who received a dose of less than 5 mGy, the relative risk of leukaemia for patients who received a cumulative dose of at least 30 mGy (mean dose 51·13 mGy) was 3·18 (95% CI 1·46–6·94) and the relative risk of brain cancer for patients who received a cumulative dose of 50–74 mGy (mean dose 60·42 mGy) was 2·82 (1·33–6·03).

Interpretation Use of CT scans in children to deliver cumulative doses of about 50 mGy might almost triple the risk of leukaemia and doses of about 60 mGy might triple the risk of brain cancer. Because these cancers are relatively rare, the cumulative absolute risks are small: in the 10 years after the first scan for patients younger than 10 years, one excess case of leukaemia and one excess case of brain tumour per 10 000 head CT scans is estimated to occur. Nevertheless, although clinical benefits should outweigh the small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionising radiation, should be considered if appropriate.

Funding US National Cancer Institute and UK Department of Health.

Lancet 2012; 380: 499–505

Published Online
June 7, 2012
http://dx.doi.org/10.1016/S0140-6736(12)60815-0

See Comment page 455

See Perspectives page 465

Institute of Health and Society (M S Pearce PhD, J A Salotti PhD, N L Howe MSc) **and Northern Institute of Cancer Research** (Sir A W Craft MD), **Newcastle University, Sir James Spence Institute, Royal Victoria Infirmary, Newcastle upon Tyne, UK; Radiation Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, MD, USA** (M P Little PhD, C Lee PhD, C M Ronckers PhD, P Rajaraman PhD, A B de González DPhil); **Great Ormond Street Hospital for Children NHS Trust, London, UK** (K McHugh FRCR); **Department of Nuclear Engineering, Kyung Hee University, Gyeongi-Do, South Korea** (K P Kim PhD); **Dutch Childhood Oncology Group—Longterm effects after childhood cancer**

Basic plan

- Define our cohort:
  individuals who had a CT examination as a child
- Gather information on all CT examinations of cohort
- Calculate/estimate radiation dose
- Evaluation of health outcomes of cohort
- Statistical analysis

Basic plan -> EPI-CT work packages

1. Coordination and management
2. Epidemiological methods - CRN
3. Data collection – NRPA, CRN
4. Calculation of radiation doses - NRPA
5. Biological mechanisms
6. Data analysis and interpretation – NRPA, CRN
7. Optimisation of paediatric CT - NRPA
8. Dissemination of results - NRPA

NRPA = Norwegian Radiation Protection Authority
CRN = Cancer Registry of Norway

EPI-CT work packages

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Data collection in Norway

- Joint responsibility of Cancer Registry Norway and Norwegian Radiation Protection Authority

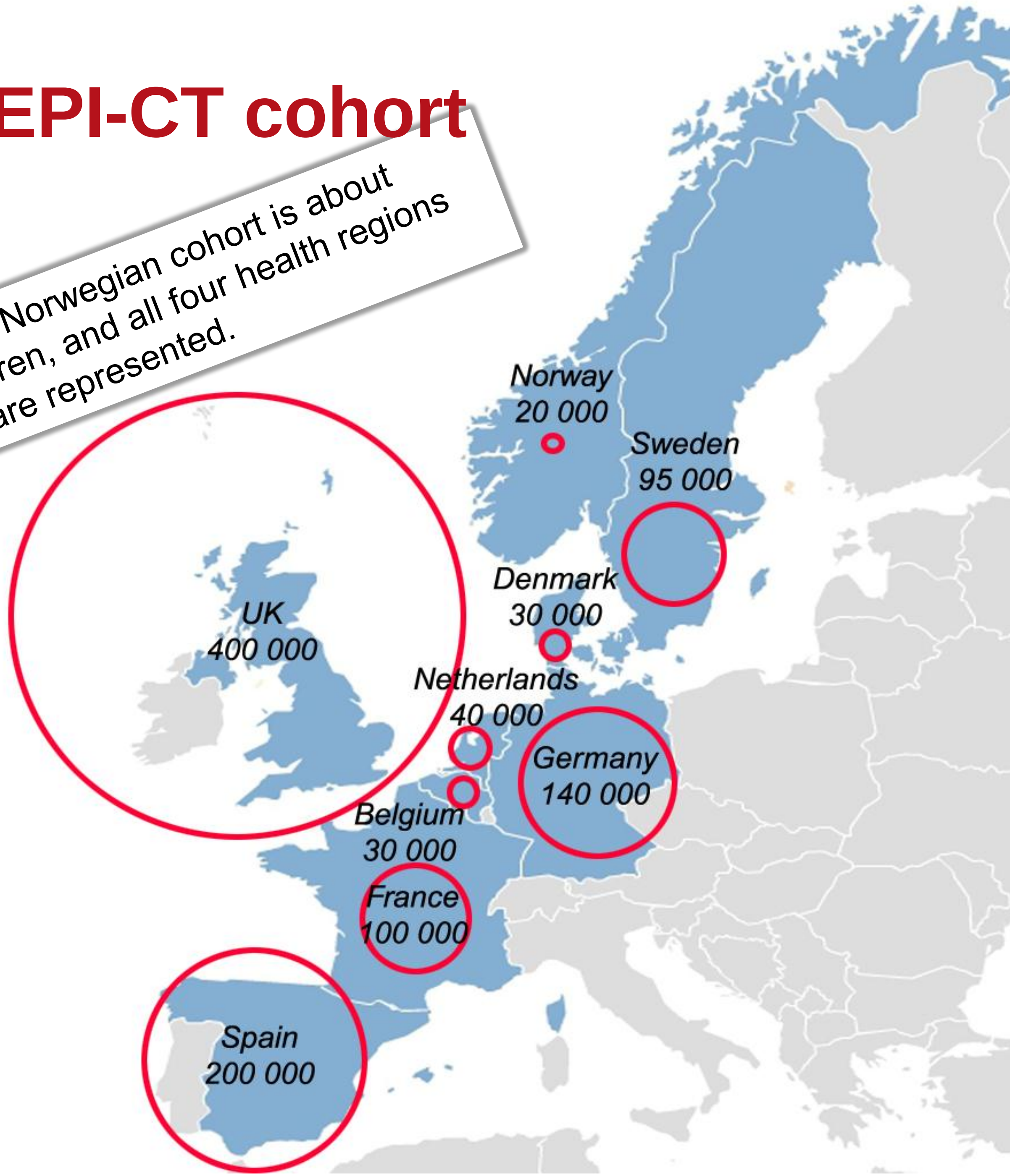
- Data collected from both RIS and PACS

Data collection in Norway

- Establish a national cohort (from RIS)
  - Paediatrics: at least 1 CT examination when aged 0-20 years
  - Include all hospitals, not only those with paediatric departments
  - Goal for Norway: 20,000 individuals
  - Multinational cohort: over 1 million individuals across Europe
- Collection of patient data and exposure parameters
  - Based on manual harvesting from RIS, and automatic harvesting from PACS by use of PerMoS software
- Collection of cancer incidence (leukaemia, brain, stomach), mortality and socio-economic status and other confounders

The EPI-CT cohort

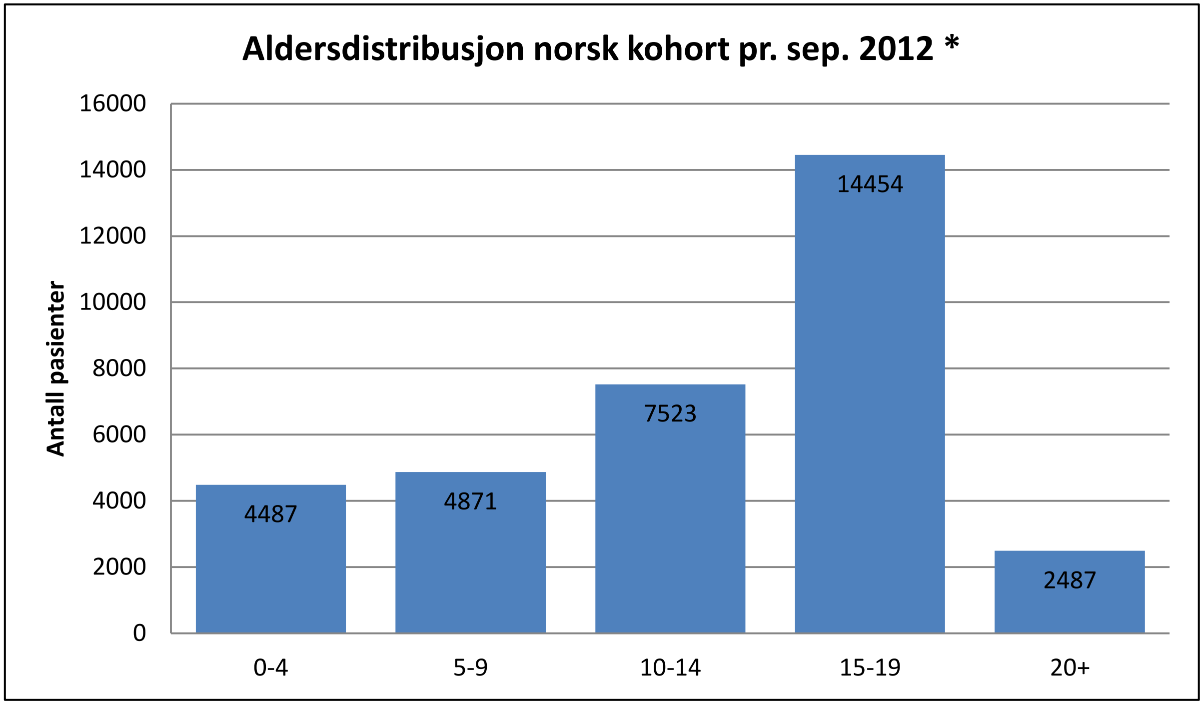
Currently the Norwegian cohort is about 35,000 children, and all four health regions in Norway are represented.



Data collection from RIS

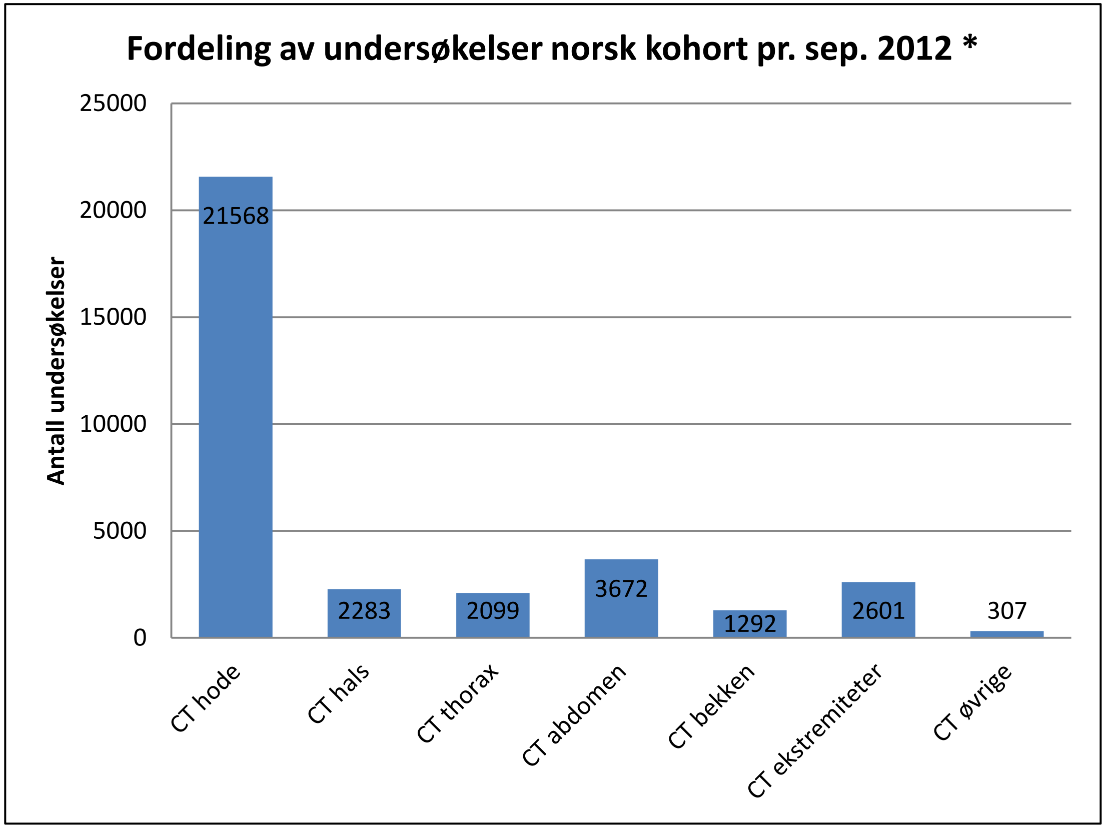
- Search in RIS for the patients that are to be included in the study (following our inclusion criteria)
- Extract relevant data items from the RIS, including patient-identifying data:
  - Age at examination, date of examination, examination type, scanner type, use of contrast, reason for examination...
  - Name, patient ID, national ID-number
- The RIS search also produces a plain text file containing patient IDs and accession numbers

Summary of RIS data extraction (so far)



*) Kohort under oppbygging, første 4 HF: Nord-Trøndelag, UNN, SUS, SSHF

Summary of RIS data extraction (so far)



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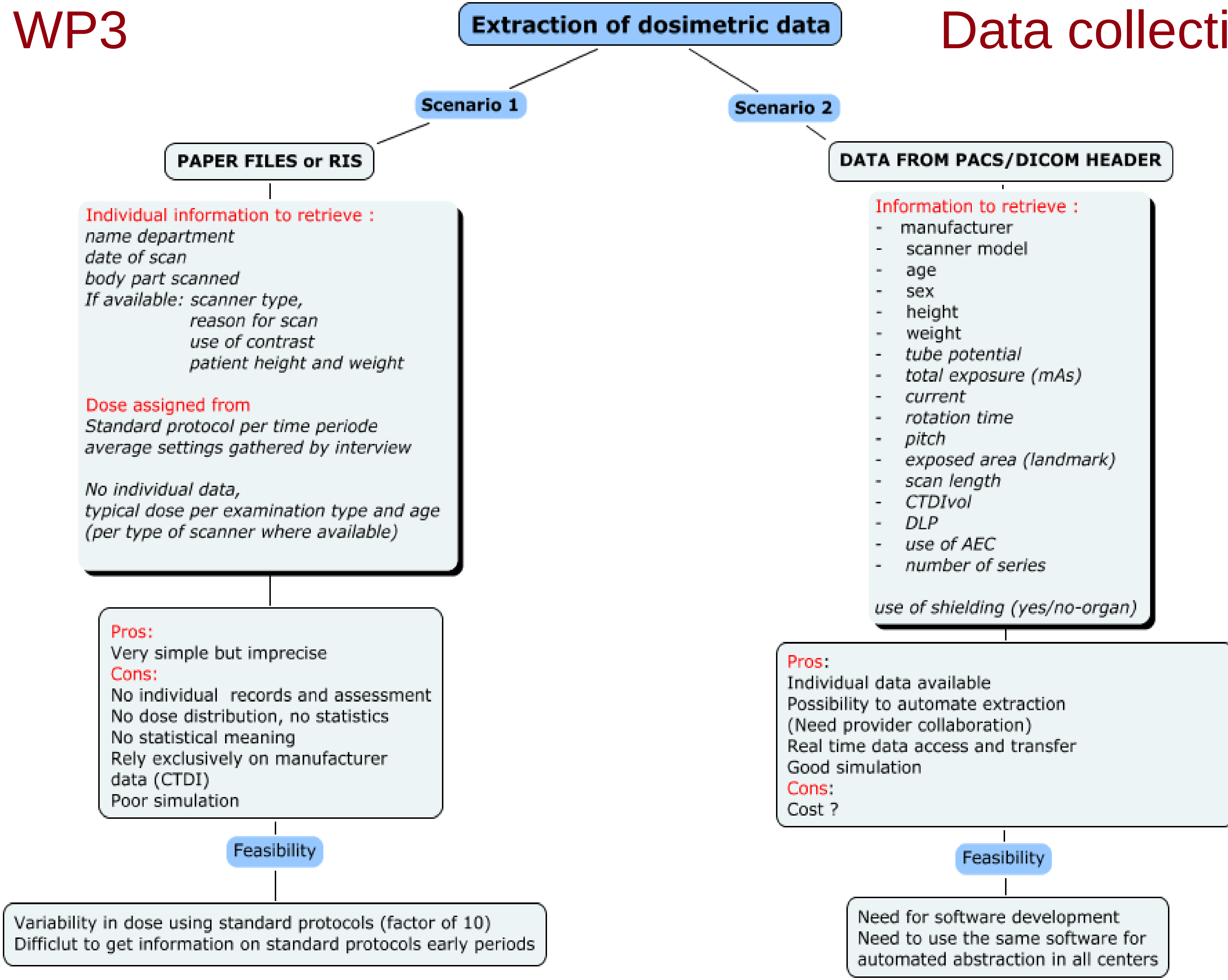
WP3 Data collection



Data collection from PACS

- Use the list of patients/accession numbers generated by RIS
- From PACS we (NRPA) take a copy of all the data that exist in the DICOM header, except patient-identifying information
- Identifying information is mapped to a pseudonym
- Contours from the CT examination images are generated, for determination of which organs were irradiated during the exam
  - Automated image segmentation and organ recognition used
- We use PerMoS software for this data extraction

Data collection from PACS

PerMoS - **Per**formance **Mo**nitoring **S**erver for Clinical Data

- Developed by Centre de Recherche Henri Tudor, Luxembourg
  - http://santec.tudor.lu/project/innomi/permos
- Java based
- Two parts to the software:
  - PerMoS Data Collector
  - PerMoS Data Manager

PerMoS Data Collector

PerMoS - **<u>Per</u>**formance **<u>Mo</u>**nitoring **<u>S</u>**erver for Clinical Data

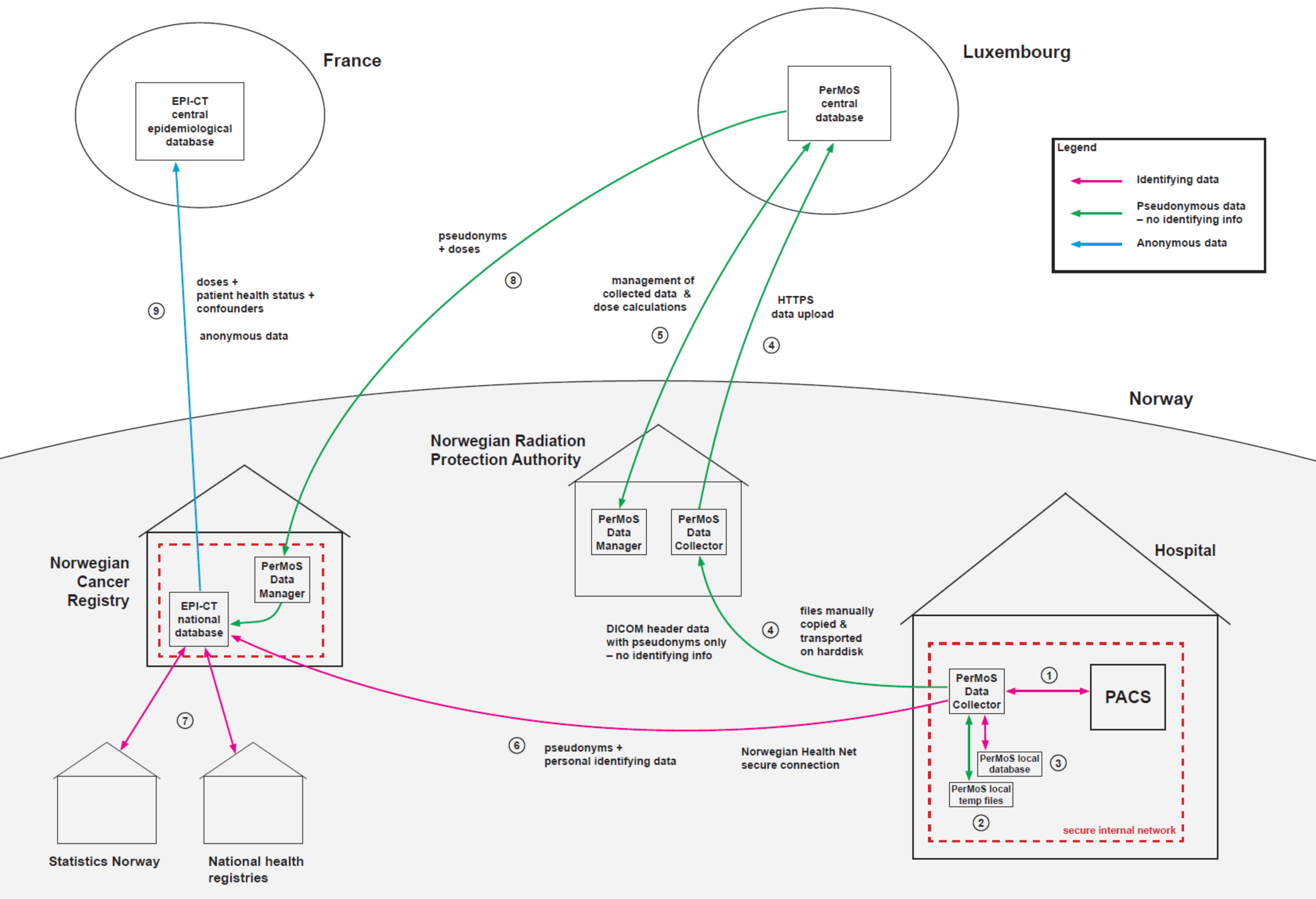
- Functions as a node on a hospital’s PACS network
- Performs automated data collection from PACS using DICOM Query/Retrieve, using either patient IDs or accession numbers
- Installed on an ordinary PC which is connected to the hospital’s PACS network
- Extracts and pseudonymises DICOM header
- Creates image contour files
- Works as quickly or as slowly as you like

PerMoS Data Manager

PerMoS - **Per**formance **Mo**nitoring **S**erver for Clinical Data

- Manages the collected data, in its own database
- Makes pseudonymised data available to the central database
- Manages the pseudonym database

Data flow for PACS data



Working packages (WP)

1. Coordination and management
2. Epidemiological methods - CRN
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Calculation of radiation doses

- Two routes:

- RIS-only examination data
  - Assign a typical dose to each examination
- PACS examination data
  - Calculate an individual dose for each examination

Dose reconstruction from RIS data in Norway

TO ALLOCATE DOSE VALUES FOR EXAMINATIONS BEFORE PACS

FROM RIS

- Date
- Hospital
- CT room and scanner
- Patient information: age, sex
- Examination type
  - hospital terminology
  - NORAKO codes
    - **No**rsk **Ra**diologisk **Ko**de
  - Clinical indication

- FROM PREVIOUS CT SURVEY 1993
  - 49 rooms
- CT manufacturer/model
- Typical scan protocol for various examination types for ADULTS
  - head, chest, abdomen, liver, kidney, spine, pelvis
  - 12 clinical indications
- Assumption
  - adult protocols were used for paediatrics
- Use new software, NCICT, to calculate organ doses
  - for the protocols used at sites in the 1990s
  - for all age groups/both sexes

WP4
NCICT β.v.

User can select phantoms from newborn to adult male/female. Reference height and weight are provided but not editable.

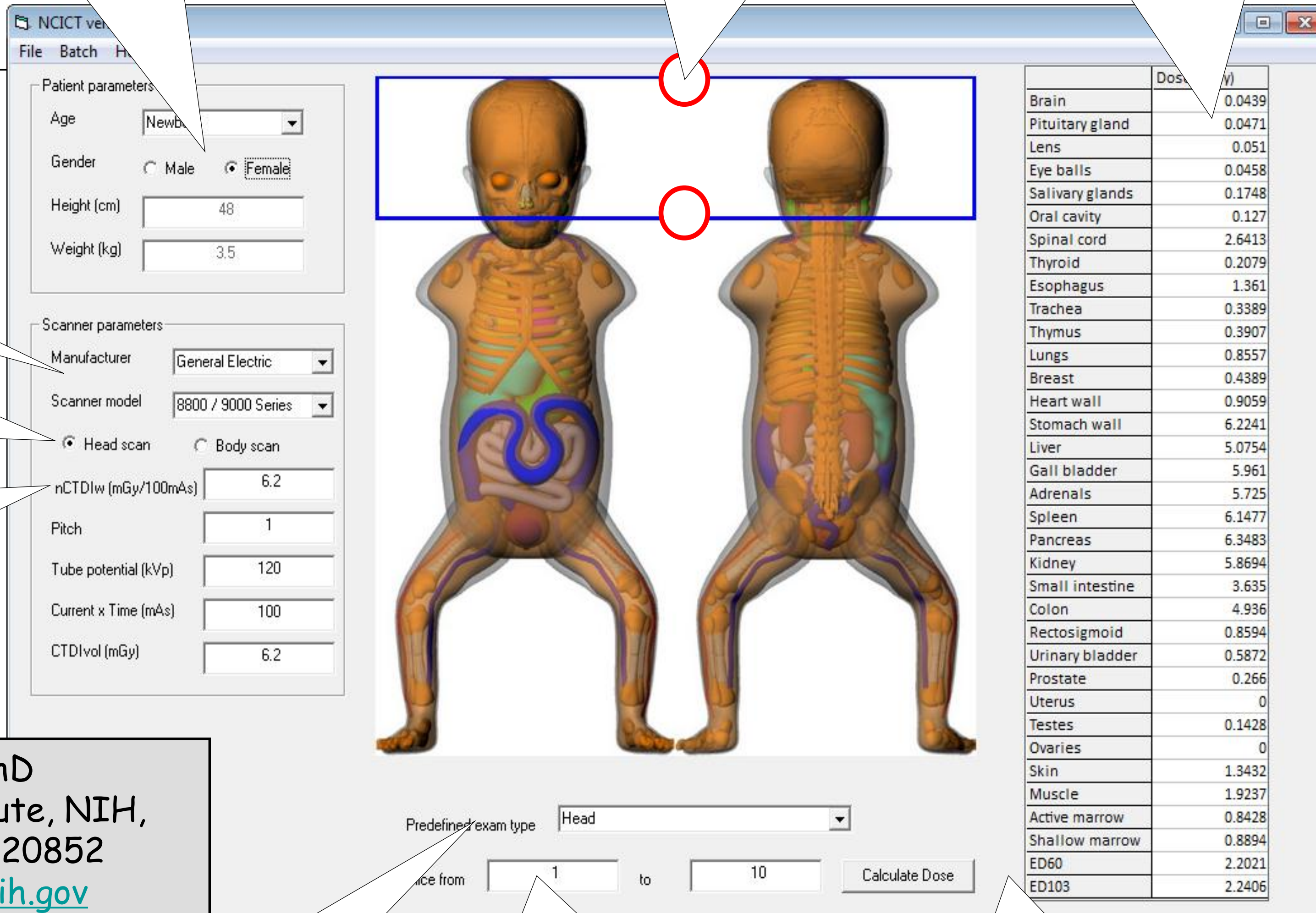
User can change the scan range by dragging upper and lower lines.

Organ/effective dose are presented here and automatically copied to clipboard. User can "paste" into Excel spreadsheet or somewhere else.

User can select from four major manufacturers. The list of scanner models are changed depending on manufacturer.

User can select from head and body filters.

CTDIw normalized to 100 mAs will be displayed from



Choonsik Lee, PhD
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Predefined scan range for different age phantoms are provided based on common scan protocol. Will be extended.

Scan start/end slice can be entered (e.g. 1 means 1 cm from the top of the head). Scan range bars will be automatically changed.

ED60 and ED103 are effective doses based on ICRP 60 and 103, respectively. "Splitting rule" in ICRP 60 was applied.

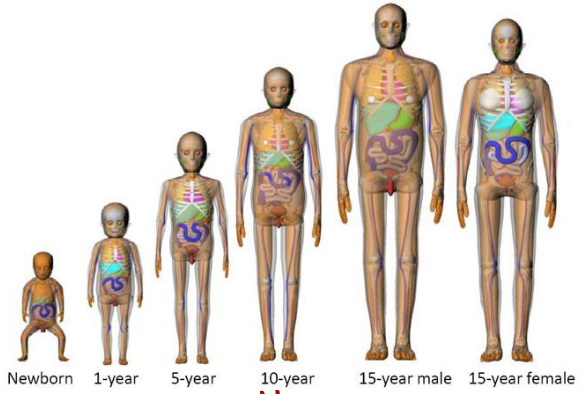
Test runs of NCICT in Norway

- GE
  - Pace, Sytec 3000
  - 9000
  - 9800, 9800Quick
  - Max
  - Prospeed
- Philips
  - Tomoscan CX
  - Tomoscan LX, SR7000
  - Tomoscan TX
- Siemens
  - Somatom Plus
- Toshiba
  - 600 HQ, XPEED
  - X-press, HS

- Beta Version of NCICT
  - New phantoms, age groups newborn, 1y, 5y, 10y, 15y, adult
- Head, Chest, Abdomen
  - Preset scan volume of interest
  - Both sex and all ages
  - Head FOV for head
  - Head (0,1y) & Body FOV chest and for abdomen
- Calculations for all scanners in Norway 1993 available in NCICT
  - **Scan protocols as used for adults in 1993 per CT room**
  - Average scan protocol per CT model
    - 120kV, mAs, pitch (couch incr/slice thickness)
  - Inter scanner variation and range in protocols (13Pace, Sytec 3000)

Dose reconstruction based on PACS data

- Aim:
  - Calculate individual organ doses for all children in the cohort
- Method:
  - Develop a uniform protocol for dose calculation
  - Develop new pediatric phantoms (many ages)
  - Develop software for Monte Carlo simulations (NCI-CT)
    - Include new CT technology and improved bone marrow dosimetry
  - Develop software for automatic dose calculation (PerMoS)
    - Exposure parameters collected in WP3
- Result:
  - Individual dose data stored in national database



Dose reconstruction based on PACS data

- PerMoS: Automatic calculation of organ doses based on PACS data
  - Data from the DICOM header is transferred
  - Image contours transferred but not full images
  - Pseudonymised data
  - Works on all PACS from all manufacturers (so far!)

- Examination data collected fed into NCICT software
  - DICOM header data and contour data
  - New pediatric phantoms, new Monte Carlo simulations

Dose reconstruction / estimation

- Examinations on PACS
  - Calculate individual dose for each examination
    - Data from DICOM header
    - Image contour data
- Examinations on RIS only
  - Pre-PACS era
  - Assign typical dose for that examination in that room at that time
    - Based on 1993 survey
    - Assuming adult protocol used

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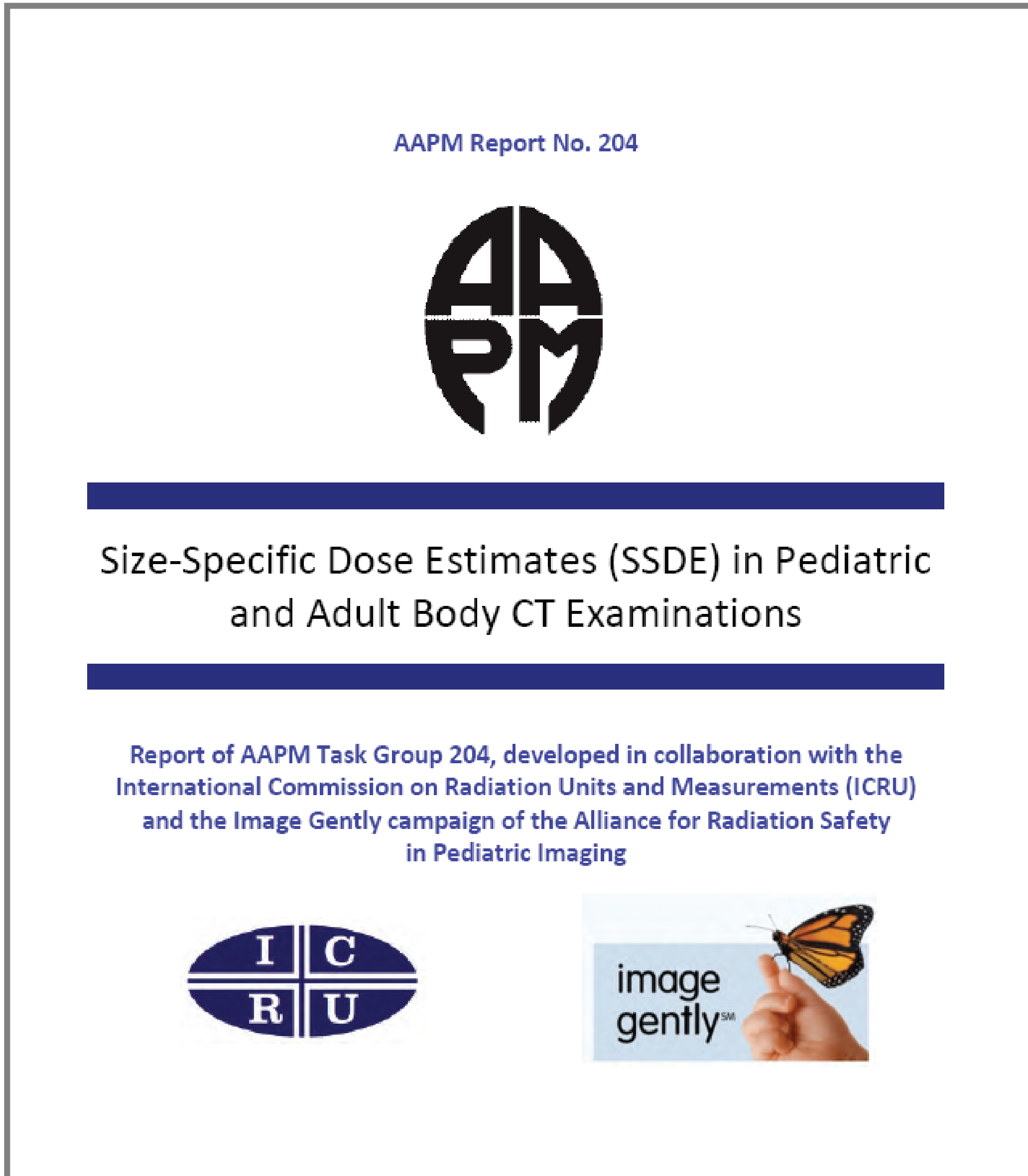
Optimization of paediatric radiology

- Aim: Optimisation of paediatric CT examinations (ALARA)
- Method (draft):
  - Map dose reduction techniques/protocols from different manufacturers and local implementation of these by hospitals
  - Evaluate dose vs. image quality
    - Physical measurements of noise, etc. in images (phantoms)
    - Evaluate image quality by expert panel of radiologists
  - Review referral criteria and establish a clinical auditing tool in PACS


AAPM Report No. 204

Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

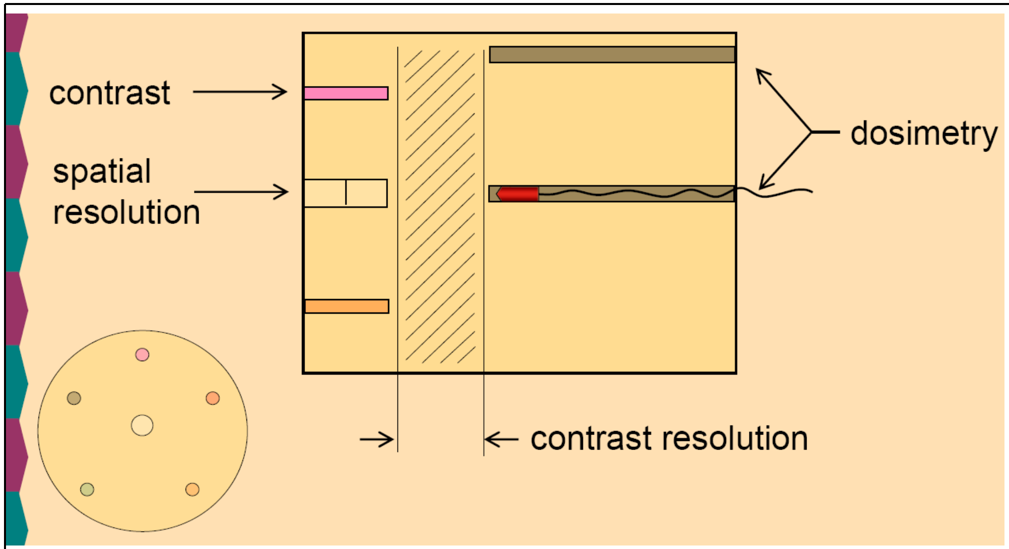
Report of AAPM Task Group 204, developed in collaboration with the International Commission on Radiation Units and Measurements (ICRU) and the Image Gently campaign of the Alliance for Radiation Safety in Pediatric Imaging

http://www.aapm.org/pubs/reports/rpt_204.pdf
(2011)

Size-specific dose estimates

- Provides a method to estimate $CTDI_{vol}$ for individual patients based on
  - Their circumference/ AP-lat dimensions
  - Conversion factors from measurements related to 16cm or 32 cm phantoms
- How do we apply this report to measurements made with the new ICRU 30cm phantom…?
  - For EPI-CT individual children…?

Optimization – Input to EPI-CT from Norway



- The new ICRU phantom
  - presented by John M. Boone, Chairman in ICRU committee on CT Image Quality and Patient Dosimetry
- Evaluates image quality (CNR, MTF) and dose (z-sensitivity profile) in the same phantom
- We need to know more about the phantom

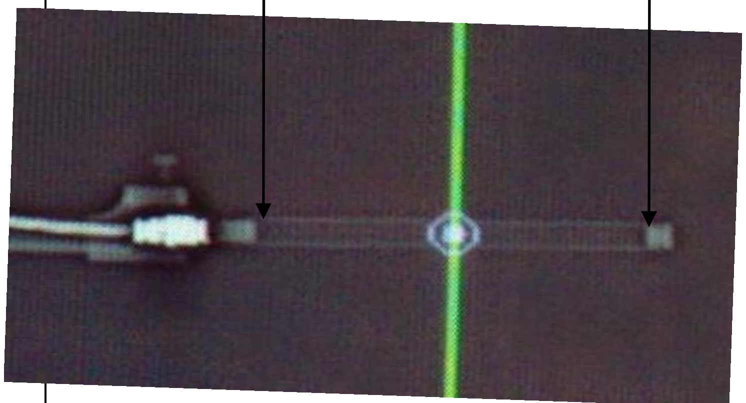
In collaboration with the partner in Luxembourg (Henri Tudor) we would like to:

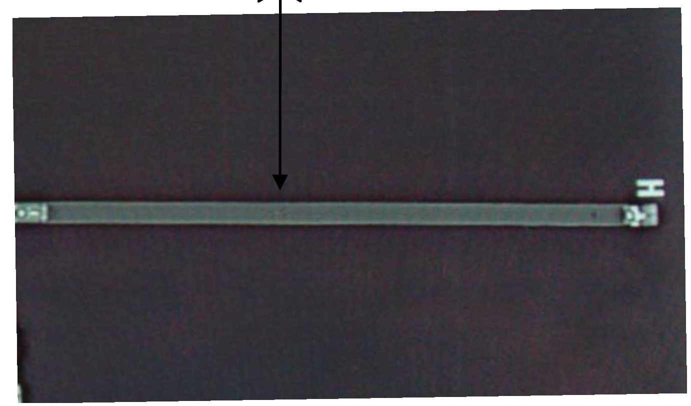
- Have this phantom manufactured by PTW
- Provide/develop software to automatically evaluate image quality and dose
- Scan it with current paediatric CT protocols for the range of current CT scanner models
  - Survey as input to optimisation
- To be compared with retrospective survey and evaluation of clinical images using the same protocols
- Input to further development of the phantom for paediatric use

Two approaches for CT dosimetry

100mm active length

0,3 mm active length





CT –ion chamber

CT-SD16 solid state detector

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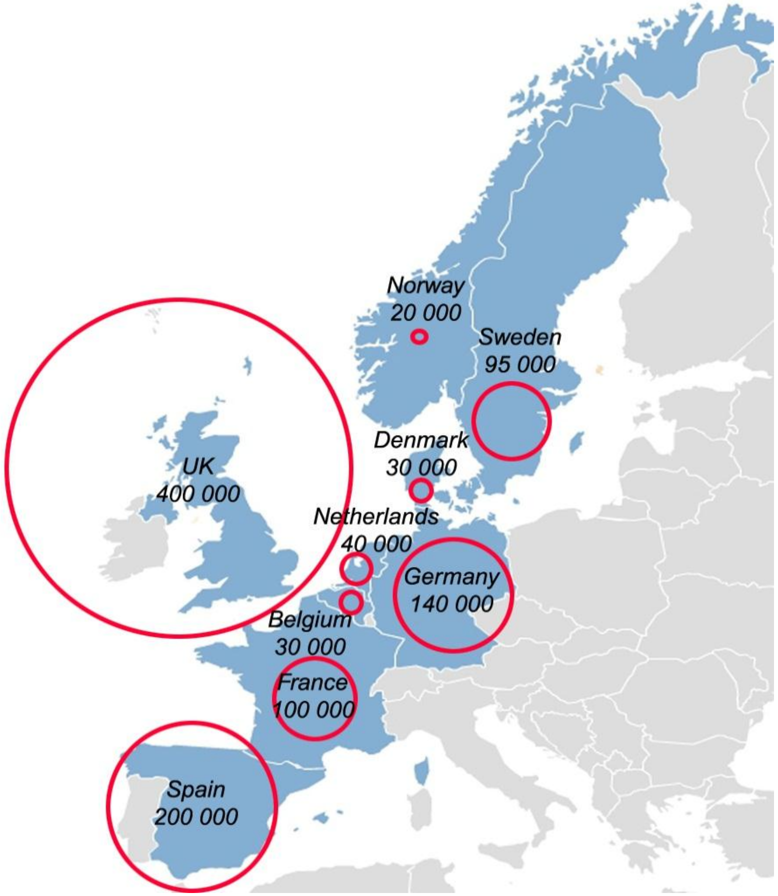
Plan of progress

Main activities and milestones in the project period (year and quarter)

Milestones throughout the project	From		To	
Establish Norwegian cohort	2011	3	2012	2
Abstraction of data from RIS/PACS	2011	3	2013	4
Finalization of Norwegian cohort	2013	3	2014	2
Protocol for dose reconstruction	2011	1	2011	4
Individual dose assessment incl. uncertainty	2013	3	2014	4
Risk estimates for leukemia	2014	3	2015	2
Risk estimates for all cancers	2014	3	2015	2
Detailed optimisation work	2011	1	2013	4
Audit tool development, PACS referral pathway	2015	1	2015	3
Dissemination activities	2015	1	2015	4

In conclusion:
New knowledge and spin-off from EPI-CT

- Organ doses in CT may exceed 50 mGy for adults
  - Previously even higher for children
- We are in the cohort size where epidemiological proofs of possible risks may be found
  - the cohort has to be followed for a long time
- National experience in use of new CT software and image quality phantoms
- Automatic gathering of data from PACS
  - Can be used in all radiology for QC, optimisation and dose records



…… Thank you for your attention!

EPI-CT in Norway: References

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noen spørsmål?

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