Effective Dose: What it gives and what it does not?

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Conflict of Interest

- None

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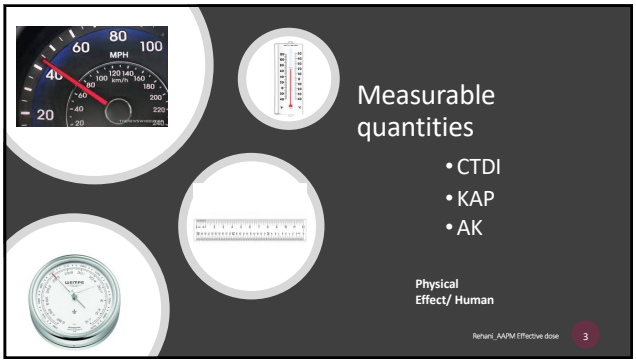

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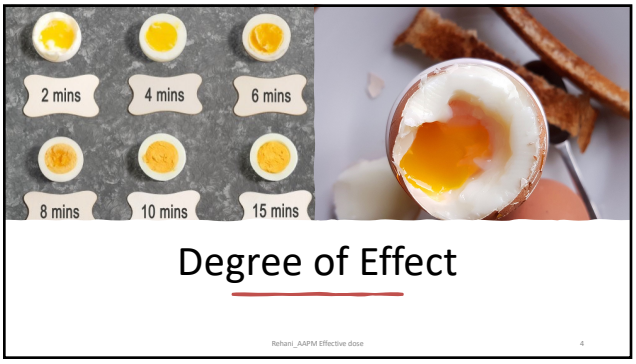

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Any example of integration of dose with potential effect?

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Is it degree of Effect or dose/input

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Is there any situation where the integration of dose with potential of complex effect is done by a single quantity?

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Effective dose (E)

- **Mean absorbed dose from a uniform whole-body irradiation that results in the same total radiation detriment as from the nonuniform, partial-body irradiation in question**
- **Weighted average of the mean absorbed dose to the various body organs and tissues, where the weighting factor is the radiation detriment for a given organ from a whole-body irradiation as a fraction of the total radiation detriment.**

Effective dose (E) = $\Sigma_T w_T H_T$

- w_T= tissue weighting factor
- H_T =equivalent doses to radio-sensitive tissues (T)

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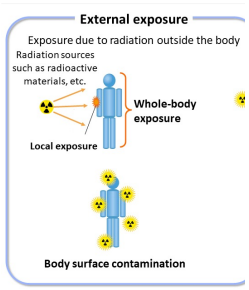
Whole body exposure



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Partial body exposure

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Unique: Effective Dose (E)

- **It is a dose quantity**
- **It includes organ doses**
- **It includes radiation risk coefficient of different tissues (w_T)**
- **It provides a single number**
- **A complex quantity like this got to have controversies & disagreements**

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Uniqueness

- Dose with implication of risk involving radio-sensitivity of many organs
- Pharmaceuticals?
- Aviation?
- Car driving?
- Pedestrian?

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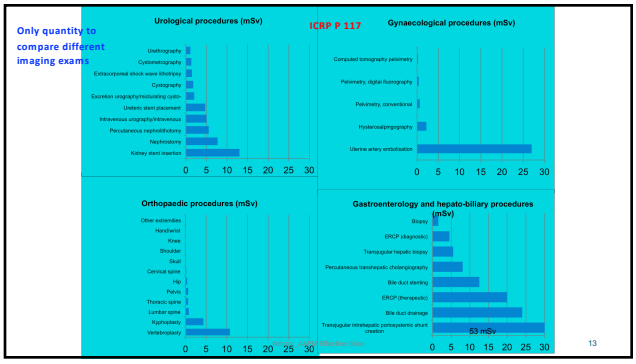
Only quantity to compare different imaging exams
ICRP P 117
Urological procedures (mSv)
Gynaecological procedures (mSv)
Orthopaedic procedures (mSv)
Gastroenterology and hepato-biliary procedures (mSv)
53 mSv
0 5 10 15 20 25 30
13

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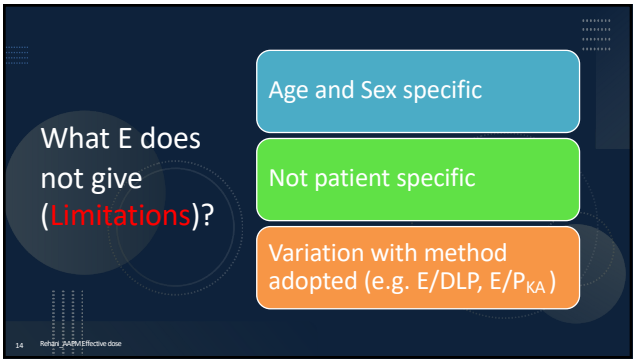
What E does not give (Limitations)?
Age and Sex specific
Not patient specific
Variation with method adopted (e.g. E/DLP, E/P_{KA})
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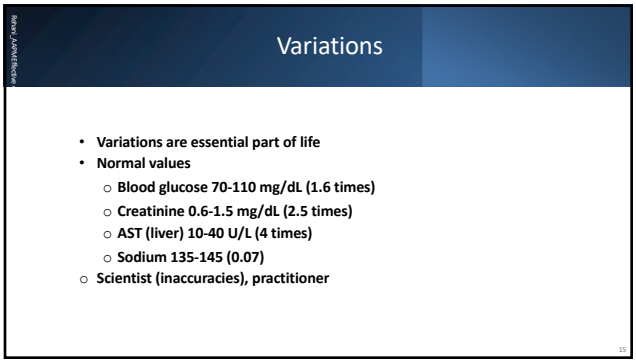
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Variations
Variations are essential part of life
Normal values
Blood glucose 70-110 mg/dL (1.6 times)
Creatinine 0.6-1.5 mg/dL (2.5 times)
AST (liver) 10-40 U/L (4 times)
Sodium 135-145 (0.07)
Scientist (inaccuracies), practitioner
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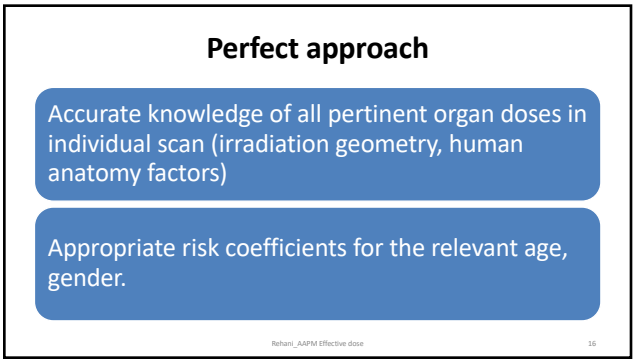
Perfect approach
Accurate knowledge of all pertinent organ doses in individual scan (irradiation geometry, human anatomy factors)
Appropriate risk coefficients for the relevant age, gender.
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Radiotherapy

- Similar situation several decades ago
- Dose to a phantom
- Dose to water
- Dose to organ/tissue (geometry of organ)
- Patient dose
- But it is confined to individual organs (need in RT is for organ)
- In imaging, we have "many organs", not just one

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Monte Carlo Simulator

- Modeling of the
  a. X-ray source spectrum (typically like NRPB R204),
  b. the patient phantoms and
  c. the interaction between X-ray photons with the patient
- Patient modelled phantom and pre-recorded data is available for each slice position on single sections, typically 1-cm scans.
- The energy deposited in each organ is recorded and stored in a lookup table.
- When a CT exam is sent to the system, the scan parameters and patient information are used to determine which simulation is run under the setup that is the closest to the actual exam, and the lookup table from that simulation is used.

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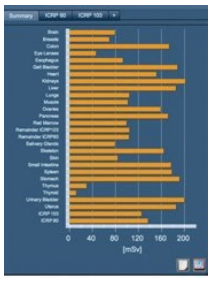

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Dose management system

- First organ doses are estimated and then one uses w_T
- Then E using standard equations by both ICRP 60 and 103.
- Is this E as per ICRP?
- Precisely speaking not
- As ICRP 110 phantom was not used
- Patient-specific E

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Review paper

Effective dose from radiation exposure in medicine: Past, present, and future

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Martin, Harrison, Rehani, Phys Med. 2020 Nov;79:87-92

1. FAQ – Can *E* be used as a dose metric for individual patients, realizing that it is a dose calculated using reference phantoms?

Yes, the dose can be assigned to individuals, but it is important to recognize that it is calculated using reference phantoms and population, age and sex averaged tissue weighting factors.

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4. FAQ – even though *E* was developed as a risk related quantity, can it be used as a dose quantity without risk estimate for many applications in medical practice?

Yes. This is an accepted use that is widely applied. It is a dose quantity and, although it has a relationship to the possible health risk from radiation, the intention is not that the user would generally have a need to quantify risks.

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5. FAQ – Can *E* be used to sum the cumulative doses from multiple examinations to individuals?

Yes. It is the only quantity which can reasonably and practically be used to sum doses from different types of exposure, so as such it can be used generally for this purpose when assessments of cumulative dose are required. However, it is considered best practice to record measured quantities so that cumulative *E* can be calculated as required using the most recent methodology [2,23].

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3. FAQ – What precautions are necessary when using *E* to represent risk for individual patients?

E can provide an approximate estimate of possible risk. However, it must be borne in mind that radiation is only one component contributing to health risks. A large proportion of patients are in the later stages of life when the potential risk from radiation is lower, and some who receive more exposures will have a reduced life expectancy because of their disease [36]. Therefore, actual risks are likely to be lower than calculated numerical values in many cases. However, there are patients who are <50 years of age and with higher life expectancy because of non-malignant disease [18,19]. In addition, special attention should be paid to young patients, as lifetime risks from exposures of children for a given dose will generally be higher than for adults [37].

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Situations where there is no need for E

- **Those where reference dose quantities are needed (Only talking about a machine e.g. machine output)**
  - **CTDIvol is also machine output**
  - **DLP is machine output with how much length exposed**
- **Radiation dose incident on the patient**
- **Radioactivity administered to a patient**

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Summary: Effective dose

- **E is a unique quantity with 44 years of use**
- **Medical exposure in addition to occupational exposure**
- **The success of E has encouraged its wider use (similar to CT)**
- **Limitations pertain to age and sex averaging and use of ICRP phantom**
- **Uncertainties in estimation need to be understood and kept in mind- they do not make E non-usable**
- **E is not an ideal solution and has many limitations**
- **Despite its limitation E has not been replaceable**
- **Cumulative E, at the moment, is the only way when series of imaging exams are involved, of different body part and mix of x-ray and nuclear imaging**
- **E should not be used for localized exposure situations like extremities, breast**

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Thank You

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