

Basing Radiation Protection on Tissue-Specific Responses to Radiation

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Invited Paper

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Outline

- uses of “dose” quantities
- where we are
 - limitations of current protection quantities E and $E_C(50)$
- where we *could* go
 - *if* our goal is individual risk prediction
- how we get there
 - tissue-specific response w_{TSR} incorporating everything we know
 - the next step: *Really Effective Dose*, D_{RE}
 - or maybe: *Fairly Effective Dose*, D_{FE}

Uses of Quantities Like Absorbed Dose and Its Relatives

retrospective uses

- protect individuals
- demonstrate
 - radiation protection
 - ALARA
 - contractual compliance
 - regulatory compliance
- promote peace of mind
- as an organizing principle to infer causation in
 - litigation (probability of causation)
 - science
 - biology
 - epidemiology
 - physical science

prospective uses

- inform risk management
- justify practices
- plan
 - safety or protection measures
 - plan interventions
- predict
 - effects on materials & processes
 - health effects in
 - individual people
 - populations
 - biota

Can one quantity be used for all that?

■ No. So where are we?

■ absorbed dose D

- fine for physical sciences
- delivered acutely, uniform, whole-body, low- LET D correlates “fairly” well with deterministic health effects
- chronic, non-uniform, high or mixed LET ...

■ LNT workarounds to relate D to human health risk

• $DDREF$

• Q or w_R

• w_T

• 50-y or $(70-t_0)$ -y integrations of $\dot{H}_T(t)$

E

$E_C(t)$

■ E , $E_C(t)$ are *not measurable!*

But what if...

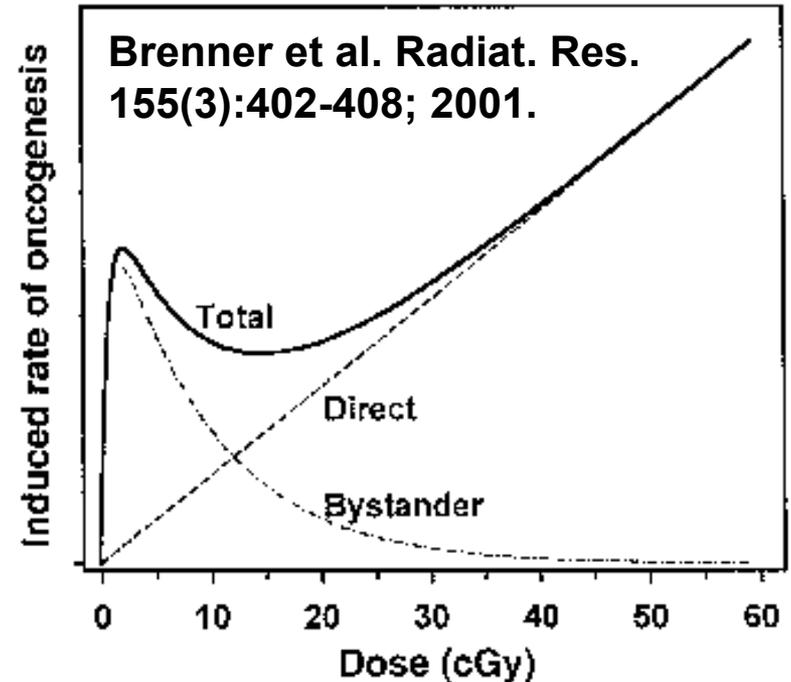
- all these corrections aren't independent?
- *DDREF* differs across radiations and tissues?
- tissue sensitivity depends on *LET* and dose rate?

And, oh, by the way, what if...

- the response of some tissues
 - isn't linear with dose or exhibited a dose threshold?
 - changes as one ages, depends on sex and genetic predisposition?
 - depends on non-radiation factors?
 - WHO says 75% of human CA is preventable (30% tobacco, 30% diet [presence *or* absence of key factors], 15% infection)
<http://wwwlive.who.ch/ncd/cancer/strategy.htm>
 - depended on the timing & sequence of rad & non-rad insults?

What we have yet to understand

- genomic instability
- bystander effects
- induction *and fading* of DNA repair mechanisms (adaptive response)
- apoptosis as an alternative to repair
- hormesis(?)
- inverse dose rate effects
- synergy



Where we are

- E , $E_C(t)$ are poor for predicting *individual* risks
 - Don't use them for predicting! Use them for radiation protection.
- we *can* protect humankind and the environment from the harmful effects of ionizing radiation by limiting dose and intake

Where could (should) we go?

- goal: improved prediction of individual risk
 - apply human data where they are known to be predictive
- must measure and record far more information on each individual
 - smoking, diet, infection, and other exposures
 - the entire time course of each exposure or condition
 - genetic predisposition

How We Get There:

Tissue-Specific Responses, w_{TSR}

- incorporate tissue-specific responses, w_{TSR} , to radiation that change throughout life and depend on
 - $\dot{D}_T(\text{age}, R, d\mathbf{j}_R / dE)$
 - instantaneous dose rate to tissue T
 - as a function of time expressed as *age*, conception to present
 - radiation type R
 - radiation energy, $d\mathbf{j}_R / dE$
 - can be integrated to give $D_T(\text{age})$
 - genetic predisposition, \vec{G} , a vector of genes
 - sex (a genetic trait!) is strong determinant of breast and thyroid CA
 - the time course of effect modifying factors, $\vec{F}_{EM}(\text{age})$
 - smoking
 - diet
 - chemical exposure
 - infection or disease
 - reproductive and hormonal status
 - and so on

Really Effective Dose D_{RE}

- D_{RE} at time t when the person's $age = AGE$ is

$$D_{RE}(AGE(t)) =$$

$$\sum_{T \text{ conception}}^{AGE(t)} \int \dot{D}_T(age) w_{TSR} \{ \dot{D}_T(age, R, d\mathbf{j}_R / dE), \vec{G}, \vec{F}_{EM}(age) \} d\text{age}$$

- D_{RE} is updated through $\vec{F}_{EM}(age)$ each time one
 - smokes a cigarette
 - doesn't eat fiber for breakfast
 - does eat animal fat or moldy peanuts
 - has an intake of human papilloma virus or HIV
 - inhales benzene, coal tar, vinyl chloride, etc.
 - uses drugs or alcohol
- D_{RE} is updated via \dot{D}_T each time one absorbs a photon

Fairly Effective Dose D_{FE}

- thresholds for bone, liver CA
- L-Q for leukemia
- does not apply deterministic limit when dose is protracted, e.g., $E_C(50)$ for Sr in bone
- uses new knowledge as it is developed
- see Pu example (paper MPM A6)

Conclusions

- Choose quantity based on its intended use
 - absorbed dose D is great for physical sciences
 - E and $E_C(50)$ can be used for protection or overprotection
 - individual risk prediction requires *Really Effective Dose*, D_{RE}
 - more appropriate protection with *Fairly Effective Dose*, D_{FE}
- D_{RE} requires
 - physical measurements on individuals and record keeping that are not presently feasible
 - genetic, biological, and lifestyle data and record keeping that are not presently feasible
- Anything simpler than D_{RE} will not incorporate factors we know are important

Acknowledgements

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Additional References

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