The Economics of Radiation Protection in Medical Settings Time for a New Paradigm

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Disclosures

- Commission Member Canadian Nuclear Safety Commission (CNSC)
- Committee Member ICRP (C3 Protection in Medicine)
- Canadian Agency for Drugs and Technologies in Health (CATDH) Health Technology Expert Review Panel Member

The opinions I express are my own and do not necessarily represent the opinions of any organization, agency, or other entity that I am, or have been, affiliated with.

Introduction

The full ALARA principle includes As Low as Reasonably Achievable taking **social and economic factors into consideration**. Given the relatively small incremental radiation dose reductions that may be realized in medical settings, and corresponding small changes to theoretical stochastic events, a conventional cost benefit approach (i.e. ICRP 1983) (e.g. $/life saved expressed as $) are less than ideal.

Alternate approaches, such as cost per unit of radiation averted (e.g. $/mSv averted), cancer induction/fatality probabilistic thresholds or thresholds relative to natural background radiation are options that may be considered.

Background and Case Scenario

	Cost	Outcome	Incremental Difference
Cost Minimization (CM)	$	=	Lowest cost
Cost Effectiveness (CE)	$	Natural units	$/year of life gained
Cost Utility (CU)	$	QALY units	$/QALY
Cost Benefit (CB)	$	$	$/$

QALY= quality adjusted life year

The table above summarizes standard approaches to economic analysis by cost ($) and various outcomes. In CB, or "*bang for your buck*" analysis outcomes are converted to $ (e.g. an additional year of life gained may be worth $50,000).

Case Study

A hospital is deciding on dose reduction options for a CT scanner. The difference in cost between the base model (with standard dose reduction options) and the dose reduction optimized model is $300K (e.g. addition of interactive reconstruction software to base dose reduction options). The average dose reduction for a single body CT is 5 mSv. The following economic analysis assumptions are simplified for the purpose of illustration.

Assumptions

Cost	Outcome
Incremental one-time net cost of $300,000 at time of purchase. For simplicity this is the only cost considered. Annual net increased costs in licensing or service contracts related to the dose reduction option are not considered. Lifetime of equipment 10 years. No depreciation costs or potential revenue are assigned at end of life. The cost of the CT procedure itself is not considered as alternate examinations are not being compared. It is assumed that the CT scan would be the ideal, optimized and justified examination. No discounting or opportunity cost adjustments made.	$50,000 per year life year saved (not quality adjusted)[a]. Background 50% lifetime chance of getting cancer with an ~ 50% chance of dying of their cancer (i.e. ~ 25% life population risk of cancer death) (Canadian Cancer Society 2017). Radiation cancer induction stochastic risk estimated at 5.5% per Sv. (ICRP 2007, p. 182). The theoretical incremental cancer incidence benefit of a net 5 mSv reduction = 5.5%/1000mSv * X%/5 mSv = 0.0275% or a net reduction of lifetime risk of cancer by ~ 30/100,000 people. The theoretical incremental cancer mortality benefit, assuming a 50% case fatality ratio, of a net 5 mSv reduction = 0.5* 0.0275% = 0.01375% or a reduction of lifetime risk of cancer death by ~ 14/100,000 people. Assume 20 years of life saved per person based on average age of onset at 60 and life expectancy ~80. **As per ICRP 103 (ICRP 2007) these theoretical risks estimates are generally not to be used for prospective or retrospective epidemiological population risk analysis but are used to guide radiation protection programs/systems.** a. mid-range of NICE proposed thresholds (NICE 2016)

Results

Economic analysis for a net reduction of 5 mSv per person.

Cost (one time)	Benefit (years)[a]	Benefit ($)[b]	Cost Benefit Ratio ($) [c]	Cost Effectiveness ($) Ratio (ICER)[d]
$300,000	0.0028	140	2143	>100,000,000

a. life years saved per person = (estimated cancer related fatalities) *20 years per life saved per 5 mSv averted = 14/100,000*20 years= 0.0028 years
b. $50,000 per year of life saved * 0.0028 years per person = $140/person
c. Δ cost ($)/Δ benefit ($) = CB = $300,000/$140 =$2,143 (i.e. cost >>> benefit. i.e. need to spend $2,143 for every $ 1 of benefit per person)
d. Δ cost ($)/Δ benefit (years of life) = CE = $300,000/(0.0028 years) = $100,714,286 per additional year of life saved
ICER= incremental cost effectiveness ratio

Alternate Options

Options	Comments
Cost per unit of radiation dose averted	A cost benefit approach where a $ value is placed on the radiation dose averted (e.g. $ per uSv or mSv averted). For the case study the CB would be $300k/5 mSv or $60k/mSv per person. If collective dose is used it would be $300K/(5 mSv * number of patients). If the department does 10,000 CT body scans per year this would result in a CB of $6/mSv-person per year.
Probabilistic approach	A risk aversion probabilistic approach similar to those used for other environmental hazards. For example the US EPA uses values of 1/10,000 to 1/1,000,000 lifetime risk for environmental carcinogens to trigger remediation actions (USEPA 2000). Setting the thresholds equal to averting a 1/10,000, 1/100,000 or 1/1,000,000 lifetime cancer risk from ionizing radiation using ICRP Publication 103 data (i.e. 5.5% lifetime risk of cancer risk per Sv) would equal to 1,818 uSv, 181 uSv and 18 uSv thresholds, respectively. These figures need to be put into the context of natural background radiation.
Thresholding Relative to Background Radiation Dose	Current USNRC and CNSC dose limits generally apply one order of magnitude lower dose rates to the public versus occupational cohorts. Given a North American annual background radiation dose of 2 to 3 mSv (USNRC 2017) this would equate to 0.2 to 0.3 mSv (200 uSv to 300 uSv) or a 1/18,000 to 1/12,000 lifetime risk of cancer using ICRP publication 103 stochastic events estimates.

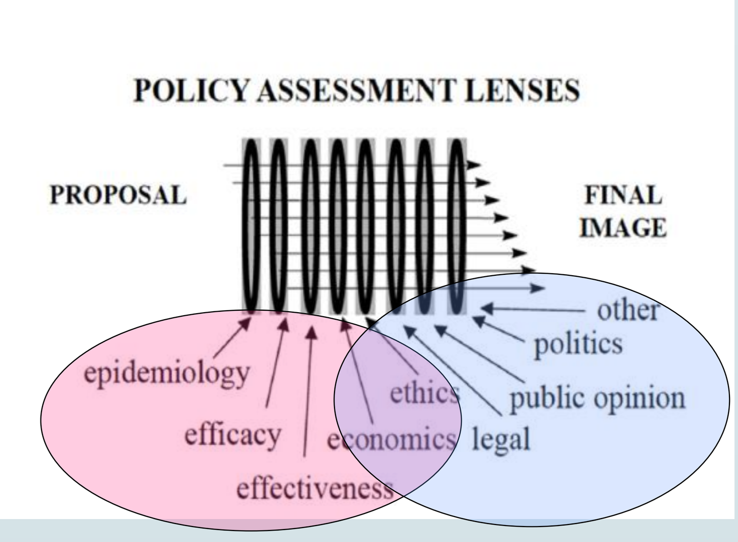
Conclusion

Given small incremental radiation dose reductions that may be realized in medical settings, and corresponding small changes to theoretical stochastic events, a conventional CB approaches (e.g. cost per averted stochastic events or years of life saved) is less than ideal.

Alternate approaches, such as cost per unit of radiation averted (e.g. $/uSv averted), cancer induction/fatality probabilistic thresholds or thresholds relative to natural background radiation are options. However, deciding on what is reasonable (i.e. $/uSv or setting thresholds) should be driven by a multistakeholder consultative process. The decision on what is a "safe" level of radiation and what are reasonable costs to make it "safer" are driven by societal values which vary from jurisdiction to jurisdiction.

The goal of this presentation is not to recommend any particular option or threshold but to start a dialogue on how to move forward.

As illustrated in the figure on the right (Demeter, 2016) policy makers take into consideration a number of lenses. Scientists are most comfortable with those on the left hand side (pink) but decisions on "what is safe" and "how low should we go" (e.g. ALARA) are strongly influenced by the lenses on the right side (blue).



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