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To Image or Not to Image - Personalized and Conscientious Medical Imaging

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Medical imaging has revolutionized patient care in the past hundred years. Yet, radiation exposure to individuals from medical imaging procedures has increased significantly and by some estimates over 8 fold since 1980, which may become a serious public health issue due to increased risk for secondary cancers from radiation exposure (1). Whether to image and how to image an individual patient is not only an ongoing technical challenge but also an ethical concern to the public health with ever increasing radiation exposure.

Ever since the first discovery of X-rays in 1895, medical imaging procedures, particularly those involving ionizing radiation such as X-rays, have been playing important roles in the diagnosis, detection, monitoring, prediction and therapy of cancers, revolutionizing ways to fight cancers at every stage of disease. Driven largely by the technological advances as well as a fee-for-service healthcare model, the use of medical imaging procedures in cancer diagnosis and therapy has increased dramatically in the past thirty years (2). It is estimated that more than 78.7 million computed tomography (CT) scans were performed in the United States alone in 2015, a 26-fold increase as compared to 3 million CT scans in 1980 (3). The same trend of increasing usage of medical imaging procedures, particularly in pediatric diagnosis and adult screening, has been observed not only in the US but also in other countries, and is expected to continue into a foreseeable future.

Recently we have also witnessed a dramatic increase in the applications of image-guidance procedures in cancer radiotherapy where medical imaging, mostly involving ionizing radiation, helps to localize the tumors and deliver tumoricidal radiation treatments with high accuracy (4). With large therapeutic doses (usually 50 to 80 Gy) delivered to the cancerous tissues via mega-voltage photon beams, one tends to think that there is no need to optimize our clinical practices to reduce the imaging doses from these image-guidance procedures. Part of this view stems from the observation that the imaging doses generally account for a small fraction of the therapeutic doses. However, in view of our current medical imaging practices, the imaging doses can potentially become a serious public health issue for the following two reasons.

First, medical imaging procedures in current clinical practices are often not personalized. That is, a ‘one-protocol-fits-all’ practice is often applied in the clinic worldwide. Essentially, the imaging protocols provided by the manufacturers are uniformly applied without

considering individual differences of patients being scanned. As such, a child could receive 2–3 times more doses than an adult from the same imaging protocol (Table 1), which could lead to increased cancer risk in children (5).

Second, medical imaging procedures are often over-applied in the clinic. This is partly due to the technological advances that have made the application of imaging procedures effortless. Another reason may come from the fact that not all clinicians are conscientious about their medical imaging practices. A recent retrospective study on 4,832 cancer patients who received a total of 142,017 imaging procedures between September 2009 and April 2014 at our institution indicated that the cumulative doses to the organs-at-risk from all the imaging procedures could reach 5% of therapeutic dose, comparable to the scatter and leakage doses (6–30% of therapeutic dose) in intensity-modulated radiation therapy of cancers (6).

The first non-personalization issue can be effectively resolved through personalized imaging protocol. The essence of personalized imaging protocol lies in that all the imaging examinations involving ionizing radiation should be performed with justification and optimized based on lesion site, anatomy, gender, age, imaging history and clinical requirement of each individual patient. Specifically, we can reduce and personalize scan range for individual patient, restrict use of fluoroscopy, or choose alternative imaging modalities such as magnetic resonance imaging and ultrasound. Also, we should apply not only site-specific but also size-specific protocols to minimize radiation doses while maintaining acceptable imaging quality. Furthermore, mobile applications and big data based tools embedded in the clinical workflow can be used to help the clinicians make informed decisions in their routine practices and reduce unnecessary imaging procedures for the benefit of individual patient.

Conscientious medical imaging can help to address the second issue, the over-usage of imaging procedures. Modern volumetric imaging procedures such as CT and kilo-voltage cone-beam computed tomography (kVCBCT) scans often irradiate more patient volumes than the therapeutic beams, depositing unnecessary integral doses to the surrounding normal tissues, which are to be spared in radiotherapy treatments. As radiation exposure from CT, kVCBCT and other radiological procedures accumulates over one's lifetime, the increasing radiation exposure to a large population around the world could lead to considerable long-term cancer risk, especially to the children (5). As decision-makers in routine patient care, clinicians must be conscientious about medical imaging in terms of its benefit and risk to each individual patient, with a constant mindset of always justifying their practices and striving to reduce unnecessary imaging procedures or seek a better alternative if available. Recently, the American Board of Internal Medicine (ABIM) Foundation has launched a “*Choosing Wisely*” campaign to create a tighter engagement between clinicians and patients and help patients make smart and effective care choices, many of which could collectively reduce unnecessary imaging procedures.

In the advent of a looming “perfect storm” created by the confluence of increasing access to advanced clinical care and increasing demand placed on healthcare providers to improve quality of patient care, personalized and conscientious medical imaging can help to mitigate

the potential secondary cancer risks induced by the non-personalized and over-applied imaging practices in cancer diagnosis and therapy. As such, a more cost-effective and sustainable public healthcare model focused on patient outcome and clinical evidence can be established for the benefit of patients in the long term (7).

While to image has become our routine practice in the clinic on a daily basis, not to image may and should be considered a worthy alternative by our clinicians while continuing to maintain a high standard of care for the individual patient, with a comprehensive understanding of the benefit and risk of medical imaging in the complex management of cancers in the modern era.

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Table 1

Comparison of mean organ doses deposited from a single CT or kVCBCT scan.

	CT		KVCBCT	
Mean Organ Doses (cGy)	Children	Adult	Children	Adult
Head Scans				
Brain	3.3	1.9	4.6	3.0
Eyes	3.6	2.3	2.5	2.0
Chest Scans				
Heart	3.1	1.7	2.4	1.3
Lungs	3.0	1.4	2.2	1.3
Pelvis Scans				
Kidneys	4.0	2.4	7.6	3.6
Red bone marrow	3.2	2.1	6.2	3.0

* CT = computed tomography; kVCBCT = kilo-voltage cone-beam computed tomography.