Austin Journal of Radiology

Austin Publishing Group

Open Access
Full Text Article

Editorial

Why are we Concerned about Imaging Dose in the Radiotherapy of Cancers?

Deng J[1]*, Zhang Y[2], Zhou L[3], Ming X[2], Zhang Y[4], Wu H[4], Bai S[3] and Feng Y[2]

[1]Department of Therapeutic Radiology, Yale University, USA
[2]Department of Biomedical Engineering, Tianjin University, China
[3]Center for Radiation Physics and Technology, Sichuan University, China
[4]Department of Radiotherapy, Peking University Cancer Hospital & Institute, China

***Corresponding author:** Jun Deng, Department of Therapeutic Radiology, Yale University, New Haven, CT, USA

Received: May 27, 2014; **Accepted:** May 28, 2014; **Published:** May 28, 2014

Introduction

A recent report by The National Council on Radiation Protection and Measurements (NCRP) indicated that there has been a steady gain in the five year survival rate for all the cancers combined together, reaching 66% by 2006, due primarily to the advances in cancer detection and cancer treatment [1]. Radiotherapy continues to be an essential part of a successful cancer treatment together with surgery and chemotherapy, with 50% of all patients receiving radiation therapy for the management of their cancers [1].

Modern radiotherapy relies on routine applications of imaging procedures for accurate tumor localization, real-time patient setup and margin reduction in the radio therapeutic management of cancers, a technique known as Image-Guided Radiotherapy (IGRT) [2]. The involved technologies include Digital Radiography (DR), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), Electronic Portal Imaging (EPID), and Cone Beam CT (CBCT) etc., most of which utilizes ionization radiation [2]. Among them, Kilo-Voltage Cone Beam CT (kVCBCT) has emerged as one of the most frequently applied techniques in the clinic.

For many years, the adverse impact of diagnostic CT on the patients has been recognized and a lot of efforts have been devoted to the dose reduction and patient safety [3-7]. Approaches like the use of bowtie filter and Automated Exposure Control (AEC) are now established practices in CT. More recently, the 'Image Gently' and 'Image Wisely' campaigns have been initiated to increase awareness of the opportunities to lower radiation doses in the imaging of children and adults, respectively [8,9]. However, similar investigations on CBCT have largely been missing, due primarily to the early stage of CBCT applications in the clinic and some misunderstandings of the imaging doses in the context of radio therapeutic doses.

Steadily increasing imaging doses in IGRT

The ultimate goal of radiotherapy is to ablate the cancerous tissues with lethal doses from radiation beams while largely sparing the adjacent normal tissues and critical structures. With large therapeutic doses delivered to the tumor volume, it is not uncommon to think that there is no need to optimize our clinical practices to reduce the imaging doses to the patients from these routine imaging procedures during IGRT. Part of this view stems from the observation that the imaging doses merely accounted for a small fraction of the therapeutic doses if the imaging dose per procedure was compared to the therapeutic dose per fraction [10-13]. With the technological advancement, the newer model of imaging devices could result in lower imaging doses per procedure as compared to older models [14]. However, our recent analysis on the imaging patterns and clinical practices indicates that the cumulative imaging doses to the patients could be of serious concern [15]. Primarily, we are concerned about the imaging doses in cancer radiotherapy for the following three reasons:

1. Medical imaging procedures are increasingly used in the radiotherapy nowadays, many of which are non-personalized and non-optimized. In comparison to a typical therapeutic dose of 180 cGy delivered to the tumor in one fraction, a typical kVCBCT scan would deposit 1-12 cGy to various organs-at-risk (OARs) in a patient depending on patient size, organ, scan settings and scan mode, accounting for 1-7% of therapeutic dose [10-13]. However, with sub-optimal settings (e.g., larger scan range than clinically needed), some critical structures such as testes would receive up to 400% more doses from a kVCBCT scan than the therapeutic mega-voltage beams [16]. In addition, with non-personalized settings (e.g., 'one-protocol-fits-all' approach currently used in the clinic), pediatric patients who are more susceptible to radiation damage will receive 2 to 3 times more doses than the adult due to much reduced tissue attenuation [17-19].

2. Many imaging procedures are repetitively applied in the clinic, some of which should be avoided. It has been reported that due to over-utilization, more than one fourth to one third of CT and other diagnostic imaging procedures are administered to the patients without justification in the clinic [1,3,20-21]. According to our recent study, the mean doses from various imaging procedures (CT simulations, kV portal, MV portal and kVCBCT) to the patient were 8.3 cGy to the brain, 10.5 cGy to the lungs and 19.2 cGy to the red bone marrow, respectively [15]. As one or more of those imaging procedures were applied more than once to the patient, the cumulative imaging doses during one's treatment course were alarmingly high, with brain dose reaching up to 143 cGy, lung dose up to 258 cGy, and red bone marrow dose up to 172 cGy, respectively, significant enough to impact the clinical outcome if not carefully accounted for.

3. Unlike radiotherapy's treatment dose, the concomitant imaging dose is not target-focused and is widely deposited across the 3-dimentional volume of the patient. Modern volumetric imaging

Citation: Deng J, Zhang Y, Zhou L, Ming X, Zhang Y, et al. Why are we Concerned about Imaging Dose in the Radiotherapy of Cancers?. Austin J Radiol. 2014;1(1): 3.

procedures such as kVCBCT scans often irradiate 45-1600% more patient volumes than the therapeutic mega-voltage beams depending on patient size and tumor volume, adding 21-26% more integral doses to the surrounding normal tissues, which are to be spared in the mega-voltage beam radiotherapy treatments. This collateral damage is unfortunately unavoidable due to the current design and implementation of CBCT scans in the clinic. While the benefit of clinically justified imaging scans will undoubtedly outweigh the cancer risk they might pose to the patients, redundant and often unjustified imaging procedures could lead to considerable cancer risk in the long term, especially to the children [22].

New approaches for reducing imaging doses

In the past few years, there have been numerous technical developments in reducing the imaging doses from CT, CBCT and other imaging procedures used in diagnostic radiology and radiation oncology [23-27]. While it is important to develop new algorithms and methods for personalized and optimized low-dose imaging procedures, it is even more critical to address the concern of ever increasing imaging doses by focusing our efforts on the clinicians who are the actual decision-makers in routine patient care. Hence, we propose the following two approaches:

1. Empower the clinicians with efficient tools to justify their practices and reduce imaging procedures. Needless to say, the clinicians nowadays are subject to increasing pressure in their clinical works such as the concerns of the throughput, as well as legal and economic matters. IT tools embedded in the clinical workflow and enabled with decision support will therefore be highly desired to eliminate the redundant and unnecessary examinations where possible, or to help the clinicians to select alternative examinations with minimal radiation exposure [28-31]. One of such tools is a computerized physician order entry (CPOE) which provides decision support to the clinicians in real-time during their regular workflow [28-29]. According to one recent study, with CPOE the physicians actually improved on the 25% of their diagnostic imaging orders initially prompted as inappropriate [30]. Another tool of this kind is an iPhone App termed CT Gently which can be used to estimate organ dose and associated cancer risk from a CT or CBCT scan for an individual patient based on one's anatomy and scan mode [31]. With optimized settings generated for the specific patient, the doses to organs-at-risk could be reduced by 50-80% in comparison to the non-optimized settings, which could help increase the awareness about the safe and appropriate applications of medical imaging in the clinic [8-9]. With the increasing use of CT and CBCT in the diagnosis and image-guidance for radiation therapy, utilization of imaging procedures justified by medical need should become a standard of care for all the patients.

2. Educate the clinicians as well as the general public on the latest imaging technologies. Modern imaging modalities often produce different types of exposure information for quality control purposes, yet this information does not typically reflect the actual dose received by a particular patient. Thus, to obtain the organ-specific absorbed doses or the whole-body effective doses, a patient-specific multi-modality dose tracking mechanism would be required to convert the reported exposure metrics into patient-specific organ dose in a spatial-temporal fashion [31-34]. The aforementioned CT Gently iPhone App is such a tool that can be used to generate patient-specific organ dose directly based on scan settings and scan mode [31]. With 4D CT/MRI imaging and 4D non-uniform rational b-splines (NURBS) algorithm, a dynamic patient phantom can be developed to model the cardiac and respiratory motions and to study their effects on medical imaging [32-34]. As such, an accurate estimation of organ doses will be made possible with such a 4D dose tracking mechanism in place, which could potentially contribute to a better tumor control for the cancer patients due to dynamic account of patient dose distributions not only spatially but also temporally. This would be most efficient if implemented in the modern Electronic Medical Record (EMR) system. As different imaging modalities produce different amount of radiation exposure to various organs-at-risk, a comprehensive analysis of the imaging dose and dose patterns could provide further insight into the efficacy and the benefit-to-risk ratio of the imaging procedures in the radiotherapeutic management of cancers [35]. Through the education of the clinicians, informed decisions on imaging procedures and radiation treatments can be made based on detailed knowledge of cumulative doses from various imaging modalities to various organs of individual patient.

Conclusion

Over-utilization of modern imaging procedures in radiotherapy could inflict a large amount of excessive imaging doses to the cancer patients whose organs are already burdened with direct and indirect exposure from radiation treatments. Educating the clinicians and empowering them with efficient tools to reduce imaging procedures could help create the most optimal practice environment to minimize radiation exposure and improve the quality of care in the long battle against the cancers with radiotherapy.

References

1. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States: recommendations of the National Council on Radiation Protection and Measurements. Report no. 160. Bethesda, MD: NCRP, 2009.

2. Dawson LA, Sharpe MB. Image-guided radiotherapy: rationale, benefits, and limitations. Lancet Oncol. 2006; 7: 848-858.

3. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007; 357: 2277-2284.

4. Mettler FA Jr, Thomadsen BR, Bhargavan M, Gilley DB, Gray JE, Lipoti JA, et al. Medical radiation exposure in the U.S. in 2006: preliminary results. Health Phys. 2008; 95: 502-507.

5. Reid J, Gamberoni J, Dong F, Davros W. Optimization of kVp and mAs for pediatric low-dose simulated abdominal CT: is it best to base parameter selection on object circumference? AJR Am J Roentgenol. 2010; 195: 1015-1020.

6. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012; 380: 499-505.

7. Lee C, Kim KP, Long DJ, Bolch WE. Organ doses for reference pediatric and adolescent patients undergoing computed tomography estimated by Monte Carlo simulation. Med Phys. 2012; 39: 2129-2146.

8. Goske MJ, Applegate KE, Boylan J, Butler PF, Callahan MJ, Coley BD, et al. The 'Image Gently' campaign: increasing CT radiation dose awareness through a national education and awareness program. Pediatr Radiol. 2008; 38: 265-269.

9. Brink JA, Amis ES Jr. Image Wisely: a campaign to increase awareness about adult radiation protection. Radiology. 2010; 257: 601-602.

10. Islam MK, Purdie TG, Norrlinger BD, Alasti H, Moseley DJ, Sharpe MB, et al. Patient dose from kilovoltage cone beam computed tomography imaging in radiation therapy. Med Phys. 2006; 33: 1573-1582.

11. Wen N, Guan H, Hammoud R, Pradhan D, Nurushev T, Li S, et al. Dose delivered from Varian's CBCT to patients receiving IMRT for prostate cancer. Phys Med Biol. 2007; 52: 2267-2276.

12. Ding GX, Duggan DM, Coffey CW. Accurate patient dosimetry of kilovoltage cone-beam CT in radiation therapy. Med Phys. 2008; 35: 1135-1144.

13. Ding GX, Coffey CW. Radiation dose from kilovoltage cone beam computed tomography in an image-guided radiotherapy procedure. Int J Radiat Oncol Biol Phys. 2009; 73: 610-617.

14. Ding GX, Munro P. Radiation exposure to patients from image guidance procedures and techniques to reduce the imaging dose. Radiother Oncol. 2013; 108: 91-98.

15. Zhou L, Ming X, Zhang Y, Bai S, Deng J. Imaging Dose and Cancer Risk in Image-Guided Radiotherapy of Cancers, Med Phys. 2014.

16. Deng J, Chen Z, Yu JB, Roberts KB, Peschel RE, Nath R. Testicular doses in image-guided radiotherapy of prostate cancer. Int J Radiat Oncol Biol Phys. 2012; 82: e39-47.

17. Deng J, Chen Z, Roberts KB, Nath R. Kilovoltage imaging doses in the radiotherapy of pediatric cancer patients. Int J Radiat Oncol Biol Phys. 2012; 82: 1680-1688.

18. Zhang Y, Yan Y, Nath R, Bao S, Deng J. Personalized assessment of kV cone beam computed tomography doses in image-guided radiotherapy of pediatric cancer patients. Int J Radiat Oncol Biol Phys. 2012; 83: 1649-1654.

19. Zhang Y, Yan Y, Nath R, Bao S, Deng J. Personalized estimation of dose to red bone marrow and the associated leukaemia risk attributable to pelvic kilo-voltage cone beam computed tomography scans in image-guided radiotherapy. Phys Med Biol. 2012; 57: 4599-4612.

20. Fazel R, Krumholz HM, Wang Y, Ross JS, Chen J, Ting HH, et al. Exposure to low-dose ionizing radiation from medical imaging procedures. N Engl J Med. 2009; 361: 849-857.

21. Lehnert BE, Bree RL. Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support? J Am Coll Radiol. 2010; 7: 192-197.

22. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. Health Risks from exposure to low levels of ionizing radiation. BEIR VII Phase 2. Washington DC: The National Academies Press. 2006.

23. McCollough CH, Primak AN, Braun N, Kofler J, Yu L, Christner J. Strategies for reducing radiation dose in CT. Radiol Clin North Am. 2009; 47: 27-40.

24. Yu L, Liu X, Leng S, Kofler JM, Ramirez-Giraldo JC, Qu M, et al. Radiation dose reduction in computed tomography: techniques and future perspective. Imaging Med. 2009; 1: 65-84.

25. Wilting JE, Zwartkruis A, van Leeuwen MS, Timmer J, Kamphuis AG, Feldberg M. A rational approach to dose reduction in CT: individualized scan protocols. Eur Radiol. 2001; 11: 2627-2632.

26. Jones AK, Balter S, Rauch P, Wagner LK. Medical imaging using ionizing radiation: optimization of dose and image quality in fluoroscopy. Med Phys. 2014; 41: 014301.

27. Zhang Y,Deng J. Toward Personalized Imaging in Image-guided Radiotherapy. Cancer Sci Res Open Access. 2014; 1: 3.

28. Khorasani R. Clinical decision support in radiology: what is it, why do we need it, and what key features make it effective? J Am Coll Radiol. 2006; 3: 142-143.

29. Sistrom CL, Dang PA, Weilburg JB, Dreyer KJ, Rosenthal DI, Thrall JH. Effect of computerized order entry with integrated decision support on the growth of outpatient procedure volumes: seven-year time series analysis. Radiology. 2009; 251: 147-155.

30. Curry L, Reed MH. Electronic decision support for diagnostic imaging in a primary care setting. J Am Med Inform Assoc. 2011; 18: 267-270.

31. Deng J. A mobile tool for CT dose and cancer risk estimation, DI Europe, 2014; 30: 62-65.

32. Segars WP, Mahesh M, Beck TJ, Frey EC, Tsui BM. Realistic CT simulation using the 4D XCAT phantom. Med Phys. 2008; 35: 3800-3808.

33. Segars WP, Lalush DS, Frey EC, Manocha D, King MA, Tsui BM. Improved Dynamic Cardiac Phantom Based on 4D NURBS and Tagged MRI. IEEE Trans Nucl Sci. 2009; 56: 2728-2738.

34. Deng J, Nath R. 4D Dynamic Simulation of Patients Undergoing Radiotherapy, IEEE International Conference on Virtual Environments Human-Computer Interfaces and Measurement Systems (VECIMS). 2012; 1-4.

35. Zhou L, Bai S, Zhang Y, Ming X, Feng Y, Deng J. The benefit and risk of medical imaging procedures in the radiotherapy of cancers. N Engl J Med. 2014.

Austin J Radiol - Volume 1 Issue 1 - 2014
ISSN : 2473-0637 | www.austinpublishinggroup.com

Citation: Deng J, Zhang Y, Zhou L, Ming X, Zhang Y, et al. Why are we Concerned about Imaging Dose in the Radiotherapy of Cancers?. Austin J Radiol. 2014;1(1): 3.