Int. J. Radiation Oncology Biol. Phys., Vol. 67, No. 2, pp. 594–600, 2007

0360-3016/07/$–see front matter

doi:10.1016/j.ijrobp.2006.10.004

ASTRO Online CME

PHYSICS CONTRIBUTION

PORTAL IMAGING PRACTICE PATTERNS OF CHILDREN'S ONCOLOGY GROUP INSTITUTIONS: DOSIMETRIC ASSESSMENT AND RECOMMENDATIONS FOR MINIMIZING UNNECESSARY EXPOSURE

Arthur J. Olch, Ph.D.,* Mark Geurts, B.S.,† Bruce Thomadsen, Ph.D.,‡ Robin Famiglietti, M.B.A., C.M.D.,§ and Eric L. Chang, M.D.§

*Department of Radiation Oncology, University of Southern California Keck School of Medicine and Childrens Hospital Los Angeles, Los Angeles, CA; †Departments of Medical Physics and Engineering Physics and ‡Medical Physics and Human Oncology, University of Wisconsin, Madison, WI; §Division of Radiation Oncology, The University of Texas M. D. Anderson Cancer Center, Houston, TX

Purpose: To determine and analyze the dosimetric consequences of current portal imaging practices for pediatric patients, and make specific recommendations for reducing exposure from portal imaging procedures.
Methods and Materials: A survey was sent to approximately 250 Children's Oncology Group (COG) member institutions asking a series of questions about their portal imaging practices. Three case studies are presented with dosimetric analysis to illustrate the magnitude of unintended dose received by nontarget tissues using the most common techniques from the survey.
Results: The vast majority of centers use double-exposure portal image techniques with a variety of open field margins. Only 17% of portal images were obtained during treatment, and for other imaging methods, few centers subtract monitor units from the treatment delivery. The number of monitor units used was nearly the same regardless of imager type, including electronic portal imaging devices. Eighty-six percent imaged all fields the first week and 17% imaged all fields every week. An additional 1,112 cm^3 of nontarget tissue received 1 Gy in one of the example cases. Eight new recommendations are made, which will lower nontarget radiation doses with minimal impact on treatment verification accuracy.
Conclusion: Based on the survey, changes can be made in portal imaging practices that will lower nontarget doses. It is anticipated that treatment verification accuracy will be minimally affected. Specific recommendations made to decrease the imaging dose and help lower the rate of radiation-induced secondary cancers in children are proposed for inclusion in future COG protocols using radiation therapy. **© 2007 Elsevier Inc.**

Portal imaging, Pediatric, Secondary cancer, Verification.

INTRODUCTION

The goal of accurate and precise radiation therapy delivery can be achieved by verification of the treatment field position through X-ray imaging procedures at the start of treatment and at regular intervals during the course of therapy. Unnecessary radiation exposure to patients is always of concern during the delivery process of radiation therapy because of its ability to induce secondary tumor formation. A case-control study of 10,834 otherwise healthy children who underwent irradiation to the scalp for tinea capitis showed increased risks for gliomas, meningiomas, nerve-sheath tumors, and neural tumors with a strong dose–response relation found with relative risk of 20 after estimated doses of 2.5 Gy (1). In addition, children with cancer are 10 times more susceptible to radiation-induced second malignancies than adults (2). Wong *et al.* found that at 50 years, the cumulative incidence of second cancers was 58% in irradiated heritable retinoblastoma patients vs. 27% in nonirradiated patients (3).

Considerable attention by the radiology community recently has been paid to radiation exposure for children undergoing computed tomography for diagnostic purpose, estimated at 1–4 cGy, resulting in an effort to limit radiation exposure from such studies. New recommendations for reducing diagnostic doses of radiation have been published and are considered standard of care by pediatric radiologists (4, 5).

Unlike radiology, in which technique guidelines exist for reduction of pediatric radiation exposure in the field of

Note—An online CME test for this article can be taken at www.astro.org under Education and Meetings.

Reprint requests to: Arthur J. Olch, Ph.D., Department of Radiation Oncology, Children's Hospital Los Angeles, 4650 Sunset Blvd. MS #54, Los Angeles, CA 90027. Tel: (323) 669-2417; Fax: (323) 913-9773; E-mail: aolch@chla.usc.edu

Acknowledgments—We thank Dr. Rajat Kudchadker for his helpful review of this manuscript.

Conflict of interest: none.

Received July 13, 2006, and in revised form Oct 4, 2006. Accepted for publication Oct 5, 2006.

radiotherapy, no portal imaging guidelines exist in terms of field size, frequency, or number of applied monitor units. Perhaps this is so because it is thought that the unintended nontarget dose delivered during the treatment would render insignificant the exposure due to portal imaging. Examples of sources of nontarget doses separate from portal imaging are head leakage, beam shape, design and orientation, and neutron exposure. Although these sources are intrinsic to the treatment, portal imaging can contribute unnecessary and avoidable exposure to patients, especially radiation exposure outside the treatment field resulting from double-exposure techniques to visualize surrounding anatomy. We were able to identify only two articles that discussed the importance of portal image dose, one from 1991 by Jones (6) and a more recent article by one of the authors of this article (E.C.) (7). Both articles computed the dose from portal imaging for various scenarios and concluded that up to an extra 2.5 Gy or 0.75 Gy, respectively, could be delivered. Both of these articles call attention to the fact that the magnitude of these doses warrants careful consideration when institutional portal imaging practices are being developed, especially for children.

In the interest of determining and quantifying current pediatric portal imaging practices, a survey was sent to all Children's Oncology Group (COG) member institutions by the COG radiation physics subcommittee. The survey was designed to determine current practices for portal imaging and to estimate the doses given during imaging. Based on the data obtained, the COG radiation oncology committee has formulated recommendations for taking portal images that will likely be implemented as guidelines for all current and future COG protocols incorporating radiotherapy.

METHODS AND MATERIALS

The survey

Approximately 250 COG member institutions that were qualified to enroll patients on protocols using radiotherapy were sent the portal imaging survey in 2004. The questions in the survey were designed to determine portal imaging practices specifically for pediatric patients, including frequency of imaging, imaging dose, and imaging modality. The questions are shown in Table 1. Responses were received over about a 6-month period ending in early 2005.

Dosimetric evaluation

Based on the information provided by the survey, three pediatric cases were investigated to see how the doses received through portal imaging affect the dose distribution both inside and outside the target. Patient 1 was a 9-year-old male with recurrent Stage IIB neuroblastoma treated in the abdomen using anteroposterior/posteroanterior fields to 27 Gy in 15 fractions. Patient 2 was a 9-year-old female with recurrent Stage III neuroblastoma treated in the abdomen with intensity-modulated radiation therapy using an eight-field arrangement to 23.4 Gy in 13 fractions. Patient 3 was an 18-year-old male with glioblastoma multiforme treated in the spinal region using anteroposterior/posteroanterior fields to 48.6 Gy in 27 fractions. The central axis anteroposterior and lateral separations for the three cases were 19.4 cm and 24.6 cm, 16.3 cm and 25.5 cm, and 17.1 cm and 26.4 cm, respectively. Patients 1 and 2 represent the same commonly encountered pediatric treatment site treated with either a simple or complex field arrangement. Patient 3 represents a simple treatment method, but with a much higher dose. Each patient was hypothetically given portal images for all treatment fields the first week using a double-exposure technique and a single-exposure orthogonal image pair each subsequent week (the most frequent imaging scenario documented by the survey). If the treatment fields did not contain an orthogonal pair, an additional single exposure was taken in the lateral position (the treatments did include anterior fields). The imaging technique used was that of the most commonly reported modality in the survey, film in cassettes, whereas the energy used for imaging and treatment was 6 MV. To determine the number of subsequent weeks that needed orthogonal images, it was assumed that five treatments were performed each week. On the final week of treatment, patients that had fewer than three treatments remaining were not imaged. For Patient 2, who was treated with eight fields, a second imaging scenario was analyzed whereby every field (bounding area of all multileaf collimator segments) was imaged

Table 1. Questionnaire

Academic institution: yes or no?
What port film verification technique does your department use?
If using the double-exposure technique, approximately how large is the collimator aperture opened for the second exposure?
How often does your department take port film verification images during a patient's course of treatment?
On average how many fields per verification session do you image?
Please indicate the approximate proportion of portal verification images made with each modality (X-ray film/cassette, electronic portal imaging device, CR, ready pack film)
If using an electronic portal imaging device for portal verification, are images generated *before/during/after* the treatment? What percentage of all these portal images is taken ***during*** the treatment?
On *average* how many monitor units do you use for the portal imaging process per image?

	MU to inside field	MU to outside field
Double exposure		
Single exposure		N/A
Other technique		

Does your department account for monitor units delivered through the portal imaging verification process by subtracting from the daily treatment?
What X-ray energy do you use for portal verification exposures?

Abbreviations: CR = computed radiography; MU = monitor units.