International Journal of
Radiation Oncology
biology • physics

www.redjournal.org

Scientific Letter

# Radiation Safety for Pregnant Workers at a Proton Facility

**Genevieve Maquilan, MD, Marc R. Bussière, MSc, Joseph McCormack, AS, Tara Medich, MS, Andrzej Niemierko, PhD, and Helen A. Shih, MD**

***Department of Radiation Oncology, Massachusetts General Hospital, Boston, Massachusetts***

Received Sep 2, 2017, and in revised form Nov 1, 2017. Accepted for publication Nov 8, 2017.

**Summary**

Occupational radiation exposure was assessed for radiation therapy technologists (RTTs) working in passively scattered proton therapy or photon therapy to inform safety practices for pregnant radiation workers. Over 14 weeks, the mean background-corrected dose was similar for proton and photon RTTs (39.9 ± 5.4 mrem and 39.9 ± 9.0 mrem, respectively; $P = .6$). Our results support use of an equivalent radiation safety policy for pregnant radiation workers employed in either proton or photon facilities.

**Purpose:** To quantify radiation exposure of radiation therapy technologists (RTTs) in a proton treatment facility in comparison with a photon therapy facility, to inform and establish these specialized occupational safety guidelines.

**Methods and Materials:** Two groups of RTTs, consisting of 12 full-time passive scattering proton RTTs and 18 full-time conventional photon RTTs, wore an additional dosimetry badge at the waist for a period of 14 weeks. The 2 groups of RTTs were given identical instructions on the proper use of the badges. To compare exposures between passive scatter and scanning beam systems, exposure rates from activated equipment in both systems were measured.

**Results:** Over the 14-week period, the mean and standard deviation background-corrected dose for the passively scattered proton RTTs was 39.9 ± 5.4 mrem. The mean and standard deviation background-corrected dose for the conventional photon RTTs was similar at 39.9 ± 9.0 mrem ($P = .6$). Exposure rates were lower in equipment activated in a scanning beam system in comparison with those from a passive scatter system.

**Conclusions:** Radiation dose to passively scattered proton and photon radiation therapy technologists was similar when measured with a dosimeter worn at the waist over a period of 14 weeks. On the basis of these data, the departmental policy permits pregnant radiation workers to work in proton treatment areas, and the policy for pregnant workers does not differ between proton and photon radiation workers or between passive scatter and scanning beam systems. All employees are encouraged to limit time near and proximity to activated equipment. 

Reprint requests to: Helen A. Shih, MD, Department of Radiation Oncology, Massachusetts General Hospital, Francis H. Burr Proton Therapy Center, 30 Fruit St, Boston, MA 02114-2696. Tel: (617) 724-9627; E-mail: HSHIH@partners.org

Conflict of interest: none.

Int J Radiation Oncol Biol Phys, Vol. ■, No. ■, pp. 1−5, 2017
0360-3016/$ - see front matter 
https://doi.org/10.1016/j.ijrobp.2017.11.016

## Introduction

Radiation treatment facilities have occupational health and safety guidelines for their patients and employees. At facilities that additionally utilize proton therapy, these general guidelines are modified to include the special ALARA (as low as reasonably achievable) considerations needed for this type of therapy. The definition of an acceptable dose limit for radiation workers is an important component of these guidelines. The National Council on Radiation Protection and Measurements (NCRP) and the US Nuclear Regulatory Commission Federal Code of Regulations (CFR) define the annual occupational dose limit for radiation workers as 5000 mrem/y (50 mSv/y). In scenarios such as a declared pregnancy, the NCRP/CFR specify the occupational dose limit for the embryo/fetus, which is monitored using dosimeters worn at the abdomen. The dose equivalence to the embryo/fetus should be limited to 50 mrem/mo during the gestation period (1, 2). Radiation workers, such as radiation therapy technologists (RTTs), at proton facilities have dose contributing to their exposure from 4 sources: (*1*) leakage through the walls of the treatment room into the control room during patient treatments; (*2*) scatter from imaging x-rays into work areas; (*3*) dose from activated permanent equipment such as the beam nozzle; and (*4*) dose from patient-specific and reusable treatment devices activated by the proton beam.

The third and fourth sources of radiation dose constitute the main difference between the sources of exposure in proton therapy compared with photon therapy, and radiation workers in proton therapy facilities need to exercise caution, following ALARA principles, in the amount of time spent handling and their proximity to activated equipment, such as apertures, range compensators, and immobilization devices. The largest contribution to exposure comes from the activated nozzle and apertures, which are made of brass that contains a combination of copper, zinc, and lead. These materials generate isotopes of manganese, cobalt, and chromium, which have long half-lives. The apertures are stored for 3 months of decay for activity to decrease down to background levels and measured to confirm exposure before disposal. The range compensators and immobilization devices such as masks are made of plastic, which contain carbon, hydrogen, and oxygen. In contrast to brass, the activity of this material quickly decreases owing to the production of $^{14}O$, $^{15}O$, and $^{11}C$, which have half-lives of 71 seconds, 122 seconds, and 20 minutes, respectively. Figure 1 shows the measured decay of brass apertures and range compensators activated by passively scattered protons, showing a significant decrease in exposure rate in the equipment by 20 minutes after treatment.

Standard national occupational safety guidelines specific to proton therapy have not been established, and such guidelines have not been standardized for pregnant workers at proton therapy facilities. This study sought to determine whether exposure to radiation, measured with dosimeters worn at the waist, for RTTs working at proton facilities differs from that of RTTs working with photons only, to inform safety guidelines for pregnant proton radiation workers.

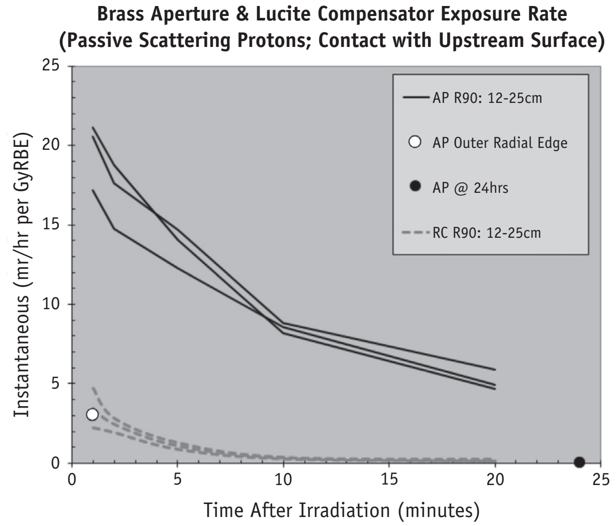


**Fig. 1.** Aperture (AP) and range compensator (RC) exposure rates after activation by passively scattered protons. 1 mR = 1 mrem. R90 is the proton water equivalent range. The solid lines represent the exposure measured on the upstream side of the aperture (side with which the protons initially interact) for beams of 12-, 19-, and 25-cm penetration. The radial edge is the side of the aperture visualized when sitting in the storage rack. The exposure from the plastic range compensator material is less than one-third of the exposure from apertures. The aperture exposure 24 hours after exposure is represented on the graph at "24 min" for purposes of simplification in visualizing the exposure rate at that time.

## Methods and Materials

For this study 12 full-time passively scattered proton RTTs wore an additional dosimetry badge, (Landauer Luxel+; Landauer, Glenwood, IL) designed to measure radiation dose from x-rays and gamma-rays, at the waist for 14 weeks. A control group of 18 full-time conventional photon RTTs also wore an additional dosimetry badge at the waist for 14 weeks. Dose contribution from neutrons was not directly measured with these dosimetry badges. Full-time therapists worked 10 hours per day for 4 days per week. Both groups were provided with the same instructions on proper use of the badges. They were instructed to wear the dosimeter at the waist, not to bring the dosimeter home, to place the dosimeter in a locker when not in use, to wear the dosimeter only when working within the department, and to notify the study coordinator if planning absence from work for more than 1 week.

We used a nonparametric Wilcoxon rank-sum test to compare the distributions of radiation doses measured in the passively scattered proton RTTs and the conventional photon RTTs over the 14-week study period. The distribution of doses