Purpose:
It is assumed that modern radiation treatment techniques such as intensity-modulated radiotherapy (IMRT), volumetric-modulated arc therapy (VMAT) and proton radiotherapy are increasing the cancer cure rates and simultaneously reducing side effects. But there are also concerns about radiation-induced malignancies caused by secondary neutron radiation, in particular, for younger patients. The aim of this study was to measure secondary neutron dose for a radiotherapy patient during typical treatments.

Methods:
In order to evaluate the neutron dose for a patient, an anthropomorphic Alderson-Rando phantom was used. The measurements were performed using CR-39 etched track detectors, placed inside and on the surface of the phantom, giving a three dimensional dose distribution and the organ doses. The neutron dose was compared with respect to treatment technique, therapy machine and radiation quality.
The CR-39 detectors were calibrated using an Am-Be neutron source and an ICRU cubic phantom. The series of measurements included photon irradiations delivered by treatment machines of the manufacturers Varian, Elekta and Siemens and the treatment techniques 3D-conformal, IMRT and VMAT. The proton irradiations were performed using active spot scanning and passive scattering techniques.

Results:
The doses were determined in terms of equivalent dose. In addition, effective dose was calculated using organ specific weighting factors of the ICRP. The effective doses for the complete course of treatment were 3.8 mSv, 3.0 mSv, 3.4 mSv, 0.7 mSv, 2.8 mSv, 20.3 mSv and 26.8 mSv for Varian 3D-conformal, Varian IMRT, Varian VMAT, Elekta IMRT, Siemens IMRT, spot scanning protons and passively scattered protons, respectively.

Conclusions:
The differences in neutron dose between the different treatment techniques for photons were not large. However, Elekta machines produce considerably lower neutron dose than Varian and Siemens machines. For proton treatments, neutron dose is higher in general and apparently higher for scattered compared to spot scanned protons.