A Bayesian hierarchical approach combined with transfer learning to study the impact of dose uncertainties on childhood cancer risk estimates following CT scans

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Abstract:

The French CT cohort includes almost 100,000 children who received at least one computed tomography (CT) scan between 2000 and 2011 in one of the 21 participating university hospitals. A previous analysis of this cohort showed statistically significant dose-response relationships between X-ray exposure and cerebral tumors and leukemia. However, several sources of uncertainty coming from CT acquisition parameters and patient's morphology exist but have never been accounted for in risk estimates. This may lead to biased risk estimates and a misquantification of the width of confidence intervals.

Bayesian hierarchical models were proposed and compared to simultaneously account for several sources of dose uncertainty when estimating the risk of childhood cancer following CT scans. An excess hazard ratio survival model with time-dependent covariates was considered as disease submodel. Berkson and misclassification errors were assumed to describe the discrepancy between observed and true CT scan parameters on the one hand and estimated and true organ doses on the other hand. The Bayesian inference was performed using an Hamiltonian Monte Carlo algorithm implemented in the R package RStan. A transfer learning approach based on joint modelling was developed to quantify dose uncertainties from an external sample of data containing all CT examinations information.

Key words: Bayesian analysis; Hierarchical models; Survival analysis; Uncertainty; Computed tomography