REVIEW

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Cumulative Radiation Dose from Medical Imaging in Chronic Adult Patients

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ABSTRACT

Chronic patients require ongoing care that results in repeated imaging and exposure to ionizing radiation for both diagnostic and therapeutic purposes. This is of concern due to the long-term effects of radiation exposure, namely the association between radiation and increased cancer risk. In this study, the scientific literature on cumulated dose of radiation accrued from medical imaging by 4 cohorts of chronic patients (cardiac disease, end-stage kidney disease, inflammatory bowel disease, and patients undergoing endovascular aortic repair) was systematically reviewed. We found that the cumulative effective dose is moderate in cardiac and inflammatory bowel disease patients, high in end-stage kidney disease patients, and very high in endovascular aortic repair patients. We concluded that radiation burden of medical imaging is high in selected cohorts of chronic patients. Efforts should be implemented to reduce this cumulative dose and its potential attendant risks.

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KEYWORDS: Chronic patients; Dose; Radiation

Over the past decade, medical use of ionizing radiation has grown rapidly and is now the largest source of radiation exposure for the United States and European Union populations.[1] In a population-based survey of radiation doses from medical imaging procedures received by about 1 million people over a 3-year period, Fazel et al[2] estimated a mean cumulative effective dose (CED) of 2.4 ± 6.0 mSv per enrollee per year. The main deterrent hampering the use of procedures with radiation is increasing awareness of the long-term effects of radiation exposure, namely the well-known association between radiation and increased cancer risk.

Concern about implications for the health of the general population due to the growing use of "high-dose" medical imaging procedures has led many researchers to focus on the relationship between lifetime risk of cancer attributable to computed tomography (CT)[3,4] and myocardial perfusion imaging (MPI).[5]

The National Academy of Sciences National Research Council reviewed epidemiological data related to health risks from exposure to radiation, published as the Biological Effects of Ionizing Radiation (BEIR) VII Phase 2 report 7.[6]

The risk estimates are derived from analyses of mortality data based on Japanese atomic bomb survivors, occupationally exposed nuclear workers, and subjects belonging to cohorts exposed to medical diagnostic or therapeutic radiation.[7] Altogether, these data provide strong evidence of an increased cancer mortality risk at equivalent doses >100 mSv, good evidence of an increased risk at doses between 50 and 100 mSv, and reasonable evidence for an increased risk at doses between 10 and 50 mSv.

Although risk models are useful and quick to calculate, they become more credible when validated by the results of epidemiological studies that directly observe health effects of radiation in the exposed populations. Results of an epidemiological cohort study assessing risk of subsequent cancers in 180,000 individuals exposed to radiation through CT scanning during childhood or as young adults in the UK have been recently published.[8] Absorbed brain and red marrow doses were estimated and excess incidences of

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leukemia and brain tumors were reported, with a positive association with CT radiation dose.

The conservative approach to addressing the issue of cumulative radiation dose necessitates defining groups of patients who would be considered at high risk for exposure to radiation. These groups would likely include chronic or recurrent patients who require ongoing care that results in repeated imaging and exposure to radiation for both diagnostic and therapeutic purposes.

In this study we will systematically review published data about the cumulated exposure to radiation in 4 selected cohorts of chronic patients. We will discuss metrics or aspects of methodological quality of identified papers. The different approaches used in estimating cumulative dose will be addressed and compared.

CLINICAL SIGNIFICANCE

- Chronic patients require ongoing care that results in repeated imaging and repeated exposure to ionizing radiation for both diagnostic and therapeutic purposes.
- In this systematic review, we found that the cumulative effective dose is moderate in cardiac and irritable bowel disease patients, high in end-stage kidney disease patients, and very high in endovascular aortic repair patients.
- The radiation burden of medical imaging on chronic patients is high and should be substantially reduced by improving appropriateness, optimization, and justification.

MATERIALS AND METHODS

We conducted PubMed/Medline, Scopus, and EMBASE searches of peer-reviewed papers on CED from diagnostic and therapeutic radiological examinations and diagnostic nuclear medicine examinations by 4 specific cohorts of nononcologic, adult, chronic, or recurrent patients (cardiac disease, end-stage kidney disease, inflammatory bowel disease, and patients undergoing endovascular aortic repair), published between 2006 and 2012. Search terms used were "radiation" + "dose," "cardiac," "dialysis," "kidney transplant," "inflammatory bowel disease," or "endovascular aortic repair."

We identified additional papers by cross-referencing bibliographies of retrieved articles. Only studies reporting CEDs accrued during episodes of care or for a period >1 year were included.

We classified population-based rates of effective doses for the study populations according to the following annual CED categories:[2] low(<3 mSv/year, the background level of radiation from natural sources in the world), moderate (>3 to 20 mSv/year, the upper annual limit for occupational exposure for at-risk workers in the European Union), high (>20 to 50 mSv/year, the upper annual limit for occupational exposure for at-risk workers in any given year in the US), and very high (>50 mSv/year).

RESULTS

Cardiac Disease

Of 1824 studies matching the search terms, 9 fulfill inclusion criteria (**Table 1**). The CED from diagnostic and therapeutic cardiac imaging procedures in a general population of 952,420 nonelderly adults has been assessed by Chen et al.[9] Among 90,121 patients who underwent ≥1 cardiac imaging procedures, the mean CED over 3 years was 23.1 mSv. The largest contributor to the CED was MPI, which was responsible for 74% of the CED, while cardiac catheterization contributed to 21%.

Einstein et al[10] investigated in a single-center study the longitudinal radiation burden of 1097 consecutive patients undergoing an MPI study, with a 20-year follow-up: the mean and median CED were 96.5 and 64.0 mSv, respectively, and 34% of patients received CED >100 mSv, including 11% who received CED >200 mSv. The largest contributor to the CED was MPI, which was responsible for 46% of the CED, followed by CT (28%) and cardiac catheterization (9%).

In a single-center study, Stein et al[11] examined 11,072 patients diagnosed with cardiac disease during a 5-year period and evaluated CED in an 8-year period. After 3 years, the mean CED was 14 mSv, and 6.2% of patients had a CED >50 mSv. This percentage increased to 14.2% and 20% after 6 and 8 years, respectively. Of that exposure, 63.5% was from the Radiology Department and the remaining 36.5% from Nuclear Medicine and Interventional Cardiology.

In a series of 50 consecutive patients admitted to a cardiology service, Bedetti et al[12] found a median CED of 61 mSv due to procedures performed during hospitalizations between 1979 and 2006. The median CED was similar to the one observed by Einstein,[10] although accrued over a longer time period. In this series, cardiac catheterization contributed to 48% of CED, while MPI and CT accounted for 16% and 17% of the CED, respectively.

A retrospective assessment of CED was led by Kaul et al[13] in 64,071 patients admitted with acute myocardial infarction through a consortium of university hospitals in the US from 2006 to 2009. In this case, the mean CED of 14.6 mSv was calculated per patient and per episode. Most of the radiation dose (67%) was due to cardiac catheterization. The remainder was accounted for by CT scans (23%) and nuclear medicine procedures (7%).

Eisenberg et al[14] used a hospital discharge summary database in Quebec to create a retrospective cohort of 82,861 patients admitted to the hospital with acute myocardial infarction between 1996 and 2006, and stratified their level of exposure to ionizing radiation from cardiac imaging and therapeutic procedures in the first year after acute myocardial infarction. They reported annual CED from all cardiac procedures of 5.3 mSv per patient-year and a 14.1 mSv