Published in final edited form as:

Health Phys. 2017 December ; 113(6): 474–518. doi:10.1097/HP.0000000000000721.

Estimated Organ Doses to Patients from Diagnostic Nuclear Medicine Examinations Over Five Decades: 1960–2010

Daphnée Villoing*, Vladimir Drozdovitch*, Steven L. Simon*, Cari M. Kitahara*, Martha S. Linet*, and Dunstana R. Melo†

*Radiation Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, Rockville, MD, USA

†Melohill Technology LLC, Rockville, MD, USA

Abstract

Ionizing radiation exposure to the general U.S. population nearly doubled between 1980 and 2006, due almost entirely to the significant increase in the number of radiologic and nuclear medicine procedures performed. Significant changes in the types of procedures and radionuclides used in nuclear medicine, as well as in detection technology, have led to notable changes over time in absorbed doses to specific organs. Our study is the first to estimate per-procedure organ doses to nuclear medicine patients and trends in doses over five decades. Weighted average organ doses per examination to 14 organs of interest were calculated for 17 examination types over 10 five-year time-periods (1960–2010), as the product of the percentage of use of each radiopharmaceutical in those diagnostic procedures based on comprehensive literature review, the administered activity, and ICRP dose coefficients; doses per radiopharmaceutical were also provided for each organ, procedure and time-period. The weighted doses to adult nuclear medicine patients from cardiac procedures increased to all organs of interest between 1960 and 2010 except for urinary bladder wall. From high radiation doses for most other procedures in the 1960s, with up to 0.7 Gy in the specific case of radioiodinated thyroid scans, organ absorbed doses generally decreased from 1960 to 1990. In contrast, during the 1990s–2000s, the weighted doses were gradually increased for some procedures, such as brain and skeleton scans. The increasing number of nuclear medicine procedures, specifically cardiac scans, and changes in weighted doses, underscore the need to monitor exposure levels and radiation-related disease risks in nuclear medicine patients.

Keywords

diagnostic imaging; nuclear medicine; patient; radiation dose

INTRODUCTION

Nuclear medicine (NM) techniques developed in the second half of the 20th century, including planar imaging, Single Photon Emission Computed Tomography (SPECT) and

For correspondence contact: Daphnée Villoing, Division of Cancer Epidemiology and Genetics, National Cancer Institute, NIH, 9609 Medical Center Drive, Room 7E520, Bethesda, MD 20892, daphnee.villoing@nih.gov.

The authors declare no conflicts of interest.

Positron Emission Tomography (PET), have become very sophisticated and been extensively involved in diagnostic testing. NM procedures rely on the intravenous, oral or inhaled administration of radiopharmaceuticals selected for their fixation on given tissues of interest. A surge of new radiopharmaceuticals has resulted in an increasing use of NM procedures over this time-period.

The number of NM procedures performed increased from 23.5 to 37 million worldwide between 1980–1984 and 1997–2007 (UNSCEAR 1988; NCRP 2009) and 7 to 18.6 million in the United States between 1980–1982 and 2006 (NCRP 1989; NCRP 2009). Thus, by 2006, half of the NM procedures in the world were performed in the United States. The estimated annual per capita effective dose from NM studies performed in the United States increased by a factor 5.5, from 0.14 mSv in 1980–1982 (NCRP 1987) to 0.77 mSv in 2006 (NCRP 2009).

According to data of the NCRP (2009), in 2006, cardiac studies accounted for 57% of the total number of diagnostic NM procedures and were responsible for 85.2% of the collective effective doses from NM procedures. Bone scan studies accounted for 20% of diagnostic NM procedures and 9.3% of collective effective doses from NM. And gastrointestinal tract studies accounted for 7% of NM procedures and 1.6% of collective effective doses from NM. On the other hand, therapeutic NM procedures represented a small percentage of the total number of NM procedures. Iodine-131 treatments for hyperthyroidism and thyroid cancer accounted for more than 90% of the total therapeutic NM procedures (NCRP 2009, ICRP 2004).

Important technical developments over the past decades that have impacted diagnostic NM procedures and led to changes with time in absorbed doses to specific organs included the development of the first molybdenum-99/technetium-99m generator, the first synthesis of ^{18}F -FDG and the development of PET/CT scanner. Furthermore, the increasing number of diagnostic NM procedures observed in the U.S. over the past decades represents a general radiation safety concern and underlines the need to monitor exposure levels.

The purpose of this study is to characterize temporal trends in organ doses received by U.S. adult patients from nuclear medicine procedures assuming some typical attributes of the patient, e.g., body size and kinetic behavior of the radiopharmaceutical. Accordingly, the authors accounted for not only the dosimetric properties of each radionuclide but also its relative frequency of use in each time period. These dosimetric data not only give a valuable historical overview of changes in radiopharmaceuticals and their relative usage in nuclear medicine, but also represent a valuable resource for epidemiologic studies that include diagnostic medical radiation.

MATERIALS AND METHODS

The usual way of estimating organ absorbed dose to a patient from a nuclear medicine procedure is by the product of the administered activity and the relevant dose coefficient. However, because different patients undergoing the same examination type, even within the same year, may have been administered different isotopes or different radiopharmaceuticals,

the authors also derived a weighted average organ absorbed dose per examination, which is a weighted average dose for each type of diagnostic NM examination in the United States within the years 1960 to 2010, with weighting factors equal to the fractional usage of radiopharmaceuticals for that examination type that were available at the time. The weighted dose as defined here has not been received by any individual patient but, rather, is representative of the weighted average dose for a type of examination considering that more than one radiopharmaceutical, each with different dosimetric properties, may have been used for the same examination type in a given time period. Hereafter, this artificial quantity simply is referred to as the *weighted dose*. The weighted dose would have the greatest use in epidemiology or in other types of descriptive analyses that do not, or cannot, account for specific isotopes or radiopharmaceuticals.

Historical information about NM diagnostic procedures performed, relative usage of radiopharmaceuticals, chemical form, and typical administered activity of each radionuclide in each five-year time-periods was based on our previous comprehensive literature survey and interviews with experienced nuclear medicine practitioners, summarized in Table 2 of Drozdovitch et al. (2015).

Accordingly, the weighted dose to male and female adult patients undergoing nuclear medicine procedures within a defined period was based on the Reference Man and Woman definitions from ICRP Publication 23 (ICRP 1975) as follows:

$$D_{T,k,l} = \sum_m p_{k,l,m} \times A_{k,l,m} \times d_{T,m} \quad (1)$$

where $D_{T,k,l}$ is the absorbed dose (mGy) to the organ or tissue T, weighted by the procedure type k, within a year l, due to radiopharmaceutical m. $p_{k,l,m}$ is the proportion of the k procedures conducted in year l with radiopharmaceutical m. $A_{k,l,m}$ is the administered activity (MBq) for the specified, k, l, and m, and $d_{T,m}$ is the dose coefficient (mGy MBq⁻¹) expressed in absorbed dose per unit administered activity for the specific T and m.

Dose coefficients were obtained from ICRP publications 53, 80 and 106 (ICRP 1987, 1998, 2008). The source of information about the ICRP dose coefficients used for the radiopharmaceuticals used in specific time-periods is based on our earlier survey (Drozdovitch et al. (2014, 2015) as shown in Table 1.

The authors also provided the organ doses per radiopharmaceutical for the administered activity specified in Drozdovitch et al. (2015), as they could be useful for retrospective dosimetry or epidemiology studies when the administered radiopharmaceutical is known. The absorbed organ dose to male and female adult patients undergoing nuclear medicine procedures, per radiopharmaceutical and within a defined period, was defined as follows:

$$D_{T,l} = A_l \times d_T \quad (2)$$

where $D_{T,I}$ is the absorbed dose (mGy) to the organ or tissue T, within a year I. A_I is the administered activity (MBq) and d_T is the dose coefficient (mGy MBq⁻¹) expressed in absorbed dose per unit administered activity for the specific organ or tissue T.

In the current study, the 17 most regularly performed types of diagnostic NM procedures were considered, including blood volume, bone marrow scan, brain scan and brain blood flow, cardiac procedures, GI bleeding and Meckel's scan, hepatobiliary scan, iron metabolism, liver scan, lung ventilation, lung perfusion, pancreas scan, kidney scan, bone scan, thyroid scan, thyroid uptake and tumor localization (Drozdovitch et al. 2015).

Estimates of the weighted doses to 14 organs of interest of adult nuclear medicine patients are described in Tables 2–15 for: thyroid, red bone marrow, lung, breast, stomach wall, liver, colon wall, kidney, urinary bladder wall, ovary, testis, brain, esophagus and heart wall. The selection of these 14 organs was primarily based on the BEIR VII report (NRC 2006) along with consideration of outcomes repeatedly evaluated in the epidemiologic risk assessment literature. Absorbed doses per radiopharmaceutical to these 14 organs of interest are also described in Tables 2–15. No further distinction was made for paired organs (e.g. kidney), or partial organ irradiation. In this study the whole organ was considered as the target organ for the dose calculations.

A few assumptions were made regarding the dose coefficients from ICRP publications:

- Dose coefficients for ^{99m}Tc-pertechnetate were used without modification for thyroid blocking for thyroid scan, thyroid uptake, and cardiac procedures based on our assumption that no thyroid blocking agents were used.
- Dose coefficients for ^{99m}Tc-pertechnetate were also used for brain scan without modification for thyroid blocking, assuming again no blocking agent was used.
- Dose coefficients for ^{99m}Tc-pertechnetate were assumed with and without a blocking agent for brain blood flow since there was no consensus in the literature on whether blocking agents were used.
- Dose coefficients for ¹³¹I-sodium iodide and ¹²³I-sodium iodide were used assuming 25% thyroid uptake for thyroid scan and thyroid uptake procedures.
- Dose coefficients of ⁵⁹Fe-citrate with oral administration were used for iron metabolism.

All dose estimates presented in Tables 2 through 15 are presented with a maximum of two significant digits (and sometimes less) to reflect the limited state of knowledge.

RESULTS

This paper provides estimates of weighted doses, as well as absorbed doses per radiopharmaceutical, to 14 different organs in five year intervals from 1960 to 2010 for all nuclear medicine adult patients in the U.S. from 17 diagnostic procedures using 49 specific radiopharmaceuticals. The organ absorbed doses derived for each examination and time-period use typical body sizes and biokinetic characteristics as specified for the Reference Man by the International Commission on Radiation Protection (ICRP, 1975). Derived

weighted doses and absorbed doses per radiopharmaceutical are provided in Tables 2–15 for breast, colon wall, kidney, liver, lung, ovary, red bone marrow, stomach wall, testis, thyroid, urinary bladder wall, brain and heart wall, for the 50-year time-period of interest.

Dose variations over time and procedures

As expected, the numerous changes in procedures and radionuclides that occurred between 1960 and 2010 led to changes with time in the weighted doses to specific organs both over time for a given procedure and over procedures within each time-period. For example, radiation doses to kidney from brain scans varied up to 102-fold between 1960–64 and 1970–1974, and radiation dose to liver during 1960–64 varied by up to 70 thousand times greater from bone marrow scan compared to thyroid uptake. The largest dose variation over time was observed for thyroid scans; the weighted thyroid doses from thyroid scans varied by up to 530 mGy between 1960–64 and 2005–10. The large variability observed highlights that historical studies of exposure cannot assume a single dose for each procedure type without additional information related to the specific radiopharmaceutical used and the associated administered activity.

Breast

Prior to 1970, the highest exposures to breast from a given procedure were due to tumor localization (61 mGy), followed by pancreas scan (9.6 mGy) and brain blood flow (8.1 mGy), as summarized in Table 2. Over the past 50 years, the weighted breast doses due to these three types of diagnostic NM procedures were reduced by factors of 13, 2.5 and 5.8, respectively. The weighted breast doses from cardiac procedures increased from 0.39 mGy in the early years (1960–1970) to 3.5 mGy. Other examination types that resulted in weighted breast doses above 1 mGy (for the entire observed time-period) were bone marrow scan, brain scan and GI bleeding and Meckel's scan.

Colon wall

Prior to 1970, the highest exposures to colon wall were due to tumor localization (57 mGy), followed by hepatobiliary scan (47 mGy) and pancreas scan (16 mGy), as summarized in Table 3. Between 1960 and 2010, weighted colon wall doses due to these three types of NM procedures were notably reduced by factors of 7.6, 3.4 and 2.9, respectively.

Exposures to colon wall from cardiac procedures increased markedly over time, from 1.5 mGy in the early years (1965–1970) to 20 mGy in the last time-period (2005–2010), as can be observed in Fig. 1. The weighted colon wall doses also increased over the five decades for brain scan, liver scan and GI bleeding and Meckel's scan, by a factor of 3.3, 79% and 36%, respectively. From the early years, doses from kidney scan and thyroid scans increased from 0.57 and 0.09 mGy, respectively, to 1.2 and 3.5 mGy in the most recent period. Other NM examinations, such as bone marrow scan, brain blood flow, iron metabolism and bone scan, resulted in weighted colon wall doses above 1 mGy over time.

Kidney

The NM examinations that delivered the highest doses to the kidney in the earlier period (1960–1964) were brain scan (411 mGy), tumor localization (98 mGy) and kidney scan (43

mGy), as summarized in Table 4. Between 1960 and 2010, weighted kidney doses due to these three types of NM procedures were substantially reduced by factors of 41, 4.9 and 17, respectively. During the 50-year period, cardiac procedures and bone scan all delivered increasing weighted kidney doses, up to respectively 28 and 6.8 mGy in the last time-period (2005–2010). Weighted kidney doses greater than 1 mGy were absorbed by the kidney from bone marrow scan, brain blood flow, GI bleeding and Meckel's scan, liver scan and pancreas scan.

Liver

The NM examinations that delivered the highest doses to the liver in the earlier period 1960–1964) were bone marrow scan (455 mGy), brain scan (109 mGy) and tumor localization (80 mGy) summarized in Table 5. Between 1960 and 2010, weighted liver doses due to these three types of NM procedures were reduced by factors of 12, 18 and 5.4, respectively. Cardiac procedures led to increasing doses over time, from 0.67 mGy in the early years (1960–1970) to 10 mGy. Except for blood volume and iron metabolism, and thyroid scan/thyroid uptake, the remaining examinations delivered weighted liver doses predominately greater than 1 mGy.

Lung

Prior to 1970, the highest exposures to lung were due to tumor localization procedures (167 mGy), followed by lung perfusion (26 mGy) and brain blood flow (22 mGy), as summarized in Table 6. Over the past 50 years, weighted lung doses due to these three types of nuclear medicine procedures were reduced by factors of 16, 2.2 and 1.6, respectively. Cardiac procedures led to increasing doses over time, from 0.72 mGy in the early years (1960–1970) to 6.9 mGy during 2005–2010. Other examination types that resulted in weighted lung doses above 1 mGy between 1960 and 2010 were bone marrow scan, brain scan, GI bleeding and Meckel's scan, pancreas scan and bone scan.

Ovary

Prior to 1970, the highest exposures to ovary were due to tumor localization (54 mGy), followed by pancreas scan (20 mGy) and brain blood flow (7.3 mGy), as summarized in Table 7. Over the past 50 years, weighted ovary doses due to these three types of NM procedures were reduced respectively by factors of 7.0, 3.4 and 3.0. Cardiac procedures and kidney scans also led to substantially increased exposures over time, from 2.0 and 0.41 mGy, respectively, in the early years (1960–1970) to 9.1 mGy and 1.9 mGy (Fig. 2). The weighted ovary doses increased slightly over the five decades for three other examinations: 43% for brain scan, 26% for GI bleeding and Meckel's scan and 18% for bone scan. Finally, exposures to the ovary remained greater than 1 mGy from hepatobiliary scan and bone marrow scans between 1960 and 2010.

Red bone marrow

The NM examinations that delivered the highest doses to the red bone marrow prior to 1960 were bone marrow scan (105 mGy), tumor localization (73 mGy), and both liver and pancreas scan (14 mGy), as summarized in Table 8. Between 1960 and 2010, weighted red

bone marrow doses due to these four types of NM procedures were reduced by factors of 17, 10, 8.2 and 2.7, respectively. Three NM examinations led to slightly increased exposures over time, by 24% for cardiac procedures (with a peak of 10 mGy between 1975 and 1985), 27% for bone scan and 22% for GI bleeding and Meckel's scan. Other NM examinations, such as brain blood flow and brain scan, resulted in weighted red bone marrow doses above 1 mGy during the study period.

Stomach wall

The NM examinations that delivered the highest doses to the stomach wall prior to 1960 were tumor localization (59 mGy), pancreas scan (17 mGy) and bone marrow scan (12 mGy), as summarized in Table 9. Between 1960 and 2010, weighted stomach wall doses due to these three types of NM procedures were reduced by factors of 8.7, 3.5 and 3.3, respectively. From the early years, doses from cardiac procedures scan and thyroid scans increased from 0.67 and 0.85 mGy, respectively, to 7.0 and 2.8 mGy in the most recent period. The weighted stomach wall doses increased were slightly over the five decades for GI bleeding and Meckel's scan by about 29%. Other NM examinations, such as brain blood flow, brain scan, liver scan and bone scan, resulted in weighted stomach wall doses above 1 mGy on average over time.

Testis

Prior to 1970, the highest exposures to testis were due to tumor localization (51 mGy), followed by pancreas scan (17 mGy) and brain blood flow (6.8 mGy), as summarized in Table 10. In 50 years, weighted testis doses due to these three types of NM procedures were reduced by factors of 8.6, 3.7 and 4.5, respectively. Exposures from cardiac procedures increased by a factor of 4.5 over the five decades. The weighted testis doses increased slightly between 1960 and 2010 from GI bleeding and Meckel's scan and brain scan by 24% and 19%, respectively. From 0.26 mGy in the early years, kidney scan delivered an increased amount of radiation, with 1.3 mGy in the most recent period. Finally, exposures to testis remained greater than 1 mGy from bone scans between 1960 and 2010.

Thyroid

Prior to 1970, the highest exposures to the thyroid were due to thyroid scans (666 mGy), followed by tumor localization (78 mGy), and thyroid uptake (67 mGy), as summarized in Table 11. Over the past 50 years, weighted thyroid doses due to these three types of diagnostic NM procedures were reduced by factors of 4.9 and 11, and by 18%, respectively. The weighted thyroid doses increased slightly over the five decades from cardiac procedures, brain scan and GI bleeding and Meckel's scan, respectively by factors of 11, 3.3 and by 29% of increase, as can be observed in Fig. 3. Other examination types that resulted in weighted thyroid doses to thyroid greater than 1 mGy between 1960 and 2010 were brain blood flow, pancreas scan and bone scan.

Urinary bladder wall

The NM examinations that delivered the highest doses to the urinary bladder wall in the earlier periods were tumor localization (54 mGy), cardiac procedures (27 mGy) and

pancreas scan (15 mGy), as summarized in Table 12. Between 1960 and 2010, several examinations such as kidney scan, bone scan, brain scan, brain blood flow, pancreas scan, hepatobiliary scan and thyroid scan, led to highly increased weighted urinary bladder wall doses by factors of 39, 18, 5.3, 3.6, 3.6, 2.6 and 2.5, respectively, as can be observed in Fig. 4. Other examinations such as GI bleeding and Meckel's scan and tumor localization led to slightly increased exposures, by 25% and 17%, respectively. In contrast, the weighted urinary bladder wall doses due to NM procedures such as bone marrow scan, lung perfusion and cardiac procedures, were reduced by factors of 4.1, 3.6 and 2.5, respectively.

Brain

Since no dose coefficients were published for brain in the ICRP publication 53 (ICRP 1987), the weighted brain doses could only be calculated in our study only for radiopharmaceuticals whose dose coefficients were updated in ICRP publications 80 (ICRP 1998) or 106 (ICRP 2008). Only two procedures could be evaluated for the time-period: GI bleeding and Meckel's scan and pancreas scan. The weighted brain doses from GI bleeding and Meckel's scan and pancreas scan increased by 22% from 2.7 mGy and from 13 mGy by and 23%, respectively, over five decades (Table 13).

Esophagus

Similar to the situation for the brain, no dose coefficients were published for the esophagus in the ICRP publication 53 (ICRP 1987). Consequently, the weighted esophagus doses could only be calculated in our study for radiopharmaceuticals whose dose coefficients were updated in ICRP publications 80 (ICRP 1998) or 106 (ICRP 2008): GI bleeding and Meckel's scan and pancreas scan. From 15 mGy prior to 1970, the exposure to esophagus from pancreas scan was reduced over five decades, by a factor 2.9. In contrast, an increase was observed for GI bleeding and Meckel's scan: from 4.5 mGy prior to 1970, the weighted esophagus doses increased by 22% over five decades (Table 14).

Heart wall

Similar to the situation for the brain and esophagus, no dose coefficients were published for the heart wall in the ICRP publication 53 (ICRP 1987). Consequently, the weighted heart wall doses could be calculated only for radiopharmaceuticals with dose coefficients from publications 80 (ICRP 1998) or 106 (ICRP 2008) of the ICRP: blood volume, cardiac procedures, GI bleeding and Meckel's scan, iron metabolism, pancreas scan and tumor localization. The NM examinations that delivered the highest doses to the heart wall prior to 1970 were tumor localization (211 mGy), GI bleeding and Meckel's scan (17 mGy) and pancreas scan (17 mGy), as summarized in Table 15. Between 1960 and 2010, the weighted heart wall doses from tumor localization were reduced by a factor 6.3. In contrast, GI bleeding and Meckel's scan and pancreas scan led to increased weighted heart wall doses by 21% and 65%, respectively. Exposure to heart wall from cardiac procedures also increased over the five decades, from 0.67 mGy in the early years to 11 mGy in the last period, as can be observed in Fig. 5. Iron metabolism studies resulted in weighted heart wall doses of 1.2 mGy between 1960 and 2010.

DISCUSSION AND CONCLUSION

To our knowledge, this is the first study to provide a comprehensive summary of weighted doses for NM patients or for individual radiopharmaceuticals, for 14 organs of interest, 17 NM procedures and 49 radiopharmaceuticals between 1960 and 2010 in the United States. A significant decrease of absorbed doses to organs was observed in the 1960s–1980s for most procedures and for most organs of interest, due to replacement by radiopharmaceuticals that delivered lower doses, in particular, those labelled with ^{99m}Tc . These trends are demonstrated in Tables 2 to 15. In contrast, with the advent of PET imaging procedures and the use of ^{18}F -FDG in recent decades, patient absorbed doses increased with cardiac procedures and GI bleeding and Meckel's scans.

Observed dose increases

The phenomenon of increasing dose in later years was mainly due to increases in administered activities of some ^{99m}Tc -labelled radiopharmaceuticals, respectively ^{99m}Tc -sestamibi (rapid 1-day protocol), ^{99m}Tc -RBC, ^{99m}Tc -DTPA aerosols or ^{99m}Tc -MDP for cardiac procedures, GI bleeding and Meckel's scan and bone scan, or to an increased use of the ^{99m}Tc -labelled radiopharmaceutical (^{99m}Tc -DISIDA in hepatobiliary scan).

As an example, the weighted doses averaged over all organs of interest from GI bleeding and Meckel's scan increased by 25% over the five decades. An absorbed dose decrease was observed between the mid-1970s and early 1990s when ^{99m}Tc -RBC (administered activity of 740 MBq) was used less and replaced by ^{99m}Tc -pertechnetate (administered activity of 185 MBq).

Another phenomenon was observed for tumor localization procedures: although the global evolution over the five decades was an absorbed dose decrease, due to a large decrease in the first two decades (1960–1979), the weighted doses, however, increased again for several organs, e.g., urinary bladder wall, heart wall, lung and kidney, by factors of 7.6, 4.4, 1.5 and 1.5, respectively, as can be observed in Fig. 6.

Cardiac procedures

The weighted doses from cardiac procedures to all organs of interest except for urinary bladder wall (and brain, absorbed dose not available) increased over the five decades, by a factor 8.6 ± 4.4 (Fig. 7). The absorbed doses to urinary bladder wall from cardiac procedures varied compared to other organs of interest, decreased by a factor of 3.7 between the 1960s and mid-1970s, and then increased by a factor of 1.6 in the mid-1970s. In the early years, ^{99m}Tc -pyrophosphate was the primary radiopharmaceutical in use (1965–1969) but was replaced, 10 years after, mostly by ^{201}Tl -chloride (1975–1979). The highest absorbed doses, averaged over all organs, were observed between the mid-1970s and early 1990s when ^{201}Tl -chloride was the most widely used radiopharmaceutical for cardiac procedures. The weighted doses then decreased for most organs, except for breast, colon and the urinary bladder wall. In the most recent time-periods, the primary radiopharmaceutical in use was ^{99m}Tc -sestamibi (rapid 1-day protocol) which accounted for 55% of the use in the late 2000s, followed by ^{99m}Tc -tetrofosmin (20% in the late 2000s). In both cases, very high

activities were administered after the early 1990s (1.11 GBq). Absorbed doses received from cardiac procedures in 2005–2010 were still high, ranging from 3.5 to 28 mGy depending on the organ of interest.

Limitations

The dose estimates presented here have limitations and uncertainties that should be understood. Primarily, and as noted earlier, organ-specific *weighted doses* are average values weighted by the relative usage of the radiopharmaceuticals used within a time-period. Accordingly, the trends presented here should be interpreted in that light as they are not necessarily representative of a specific exposure, radionuclide or radiopharmaceutical. However, organ doses per radiopharmaceutical, without weighting factors are provided in Tables 2–15 for those instances when the dose specific to a radiopharmaceutical are needed.

A second limitation is that the radiopharmaceuticals based on the survey by Drozdovitch et al. (2015) may not completely reflect all practices and usage in the United States. Some of the radiopharmaceuticals that may have been used were possibly not reported in that study, or the reported data might not be representative of all medical facilities. These limitations contribute to the overall uncertainty. Moreover, it is likely that the administered activities to various current radiopharmaceuticals may have varied since 2010. The weighted doses and absorbed doses per radiopharmaceutical from the last 5-year period (2005–2010) should therefore be used with additional caution for any study after 2010.

Another source of uncertainty is related to the values of administered activities that were used to calculate the absorbed doses. Although activity is actually administered according to the age and weight of the patient, in this study, typical administered activities were derived from an extensive literature review (Drozdovitch et al. 2015). Variations in the amount of administered activity for individual patients can lead to differences in absorbed doses that are not necessarily reflected in the findings of this study. In addition, there are uncertainties associated with organ dose estimates reflect uncertainty in dose coefficients, which are calculated from reference anthropomorphic phantoms without gender specificity and, hence, cannot be representative of all patient anatomies but only of average sized ones. The authors used a consistent methodology for all calculations, however.

The dose coefficients used in this study were provided by the ICRP publications 53 (ICRP 1987), 80 (ICRP 1998), and 106 (ICRP 2008), for which all S value ($\text{Gy.Bq}^{-1}.\text{s}^{-1}$) calculations were performed on stylized anthropomorphic phantoms, known to not be fully realistic and leading, in some occasions, to over or under-estimation of dose. With the development and publication of more realistic reference phantoms, the male and female ICRP publication 110 adult reference computational models (ICRP 2009), representing average-sized reference male, female and pediatric patients from the ICRP publication 89 (ICRP 2002), a few specific S values have been published recently (Lamart et al. 2016, Villoing et al. 2017) for a few radionuclides. Future efforts to update dose coefficients in the coming years will provide an opportunity to possibly improve the organ doses that have been derived here. In contrast to the two first types of uncertainty which are inherent to the variations amongst patients and clinical centers and, hence, probably cannot be reduced, this last source of uncertainty may be reduced with improved dose coefficients.

Most important here is the reminder that the doses presented in the main text (called weighted doses) are weighted estimates even though they assume attributes and dosimetric parameters for typical adult patients. It is clear that these doses do not apply to any identified individual. All estimates have inherent uncertainties reflecting the various limitations of the data and methodology discussed above.

In conclusion, this study summarized trends in the weighted doses to 14 different organs based on 17 types of diagnostic NM procedures commonly performed in the United States between 1960 and 2010. Absorbed doses per radiopharmaceutical are also available for the same organs of interest, procedures and time-periods. The dose estimates presented here may need to be updated in the next decade with several improvements, e.g., the use of more realistic computational phantoms for deriving dose factors, to account for any further changes in radiopharmaceutical usage proportions, as well as to account for any new medical procedures involving radionuclides that are introduced. Doses could also be calculated for brain and heart wall for more nuclear medicine procedures. The data presented here are, for the present, the most complete available for understanding the temporal changes in dose from specific types of diagnostic nuclear medicine examinations. These data represent a valuable resource for epidemiologic studies that include medical radiation either as the primary or a secondary source of exposure.

Acknowledgments

This work was supported by the Intramural Research Program of the National Institutes of Health, National Cancer Institute and the U.S. Public Health Service of the Department of Health and Human Services, Bethesda, Maryland.

References

- Droz dovitch V, Brill AB, Mettler FA Jr, Beckner WM, Goldsmith SJ, Gross MD, Hays MT, Kirchner PT, Langan JK, Reba RC, Smith GT, Bouville A, Linet MS, Melo DR, Lee C, Simon SL. Nuclear medicine practices in the 1950s through the mid-1970s and occupational radiation doses to technologists from diagnostic radioisotope procedures. *Health Phys.* 2014; 107:300–310. [PubMed: 25162420]
- Droz dovitch V, Brill AB, Callahan RJ, Clanton JA, DePietro A, Goldsmith SJ, Greenspan BS, Gross MD, Hays MT, Moore SC, Ponto JA, Shreeve WW, Melo DR, Linet MS, Simon SL. Use of radiopharmaceuticals in diagnostic nuclear medicine in the United States: 1960–2010. *Health Phys.* 2015; 108:520–537. [PubMed: 25811150]
- ICRP. Ann ICRP. Vol. 3. Oxford: ICRP; 1975. Report on the task group on Reference Man. Publication 23
- ICRP. Ann ICRP. Vol. 18. Oxford: ICRP; 1987. Radiation dose to patients from radiopharmaceuticals. Publication 53
- ICRP. Ann ICRP. Vol. 28. Oxford: ICRP; 1998. Radiation dose to patients from radiopharmaceuticals. Addendum 2 to ICRP Publication 53. Publication 80
- ICRP. Ann ICRP. Vol. 32. Oxford: ICRP; 2002. Basic anatomical and physiological data for use in radiological protection reference values. Publication 89
- ICRP. Ann ICRP. Vol. 34. Oxford: ICRP; 2004. Release of patients after therapy with unsealed radionuclides. Publication 94
- ICRP. Ann ICRP. Vol. 36. Oxford: ICRP; 2006. The optimisation of radiological protection - broadening the process. Publication 101b
- ICRP. Ann ICRP. Vol. 38. Oxford: ICRP; 2008. Radiation dose to patients from radiopharmaceuticals. Addendum 2 to ICRP Publication 53. Publication 106

- ICRP. Ann ICRP. Vol. 39. Oxford: ICRP; 2009. Adult reference computational phantoms. Publication 110
- Lamart S, Simon SL, Bouville A, Moroz BE, Lee C. S values for ¹³¹I based on the ICRP adult voxel phantoms. *Radiat Prot Dosimetry*. 2016; 168:92–110. [PubMed: 25829162]
- NCRP. NCRP Report No. 93. Bethesda, MD: National Council on Radiation Protection and Measurements; 1987. Ionizing radiation exposure of the population of the United States.
- NCRP. NCRP Report No. 100. Bethesda, MD: National Council on Radiation Protection and Measurements; 1989. Exposure of the U.S. population from diagnostic medical radiation: recommendations of the National Council on Radiation Protection and Measurements.
- NCRP. NCRP Report No. 160. Bethesda, MD: National Council on Radiation Protection and Measurements; 2009. Ionizing radiation exposure of the population of the United States.
- NRC Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation. National Academy Press: National Research Council BEIR VII; 2006.
- UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation 1988 Report to the General Assembly. United Nations Publication, sales no. E.88.IX.7; New York: 1988. Sources and effects of ionizing radiation. Exposures from medical uses of radiation, annex C.
- Villoing D, Marcatili S, Garcia MP, Bardies B. Internal dosimetry with the Monte Carlo code GATE: validation using the ICRP/ICRU female reference computational model. *Phys Med Biol*. 2017; 62:1885–1904. [PubMed: 28182580]

Fig. 1. Weighted colon wall doses, over five decades from 1960 to 2010, for six NM diagnostic procedures: brain scan (B), cardiac procedures (C), GI bleeding and Meckel's scan (GIB), liver scan (L), kidney scan (K) and thyroid scan (T).

Fig. 2. Weighted ovary doses, over five decades from 1960 to 2010, for five NM diagnostic procedures: brain scan (B), cardiac procedures (C), GI bleeding and Meckel's scan (GIB), kidney scan (K) and bone scan (Bo).

Fig. 3. Weighted thyroid doses, over five decades from 1960 to 2010, for three NM diagnostic procedures: brain scan (B), cardiac procedures (C) and GI bleeding and Meckel's scan (GIB).

Fig. 4. Weighted urinary bladder wall doses, over five decades from 1960 to 2010, for nine NM diagnostic procedures: hepatobiliary scan (HB), brain blood flow (BB), brain scan (B), GI bleeding and Meckel's scan (GIB), pancreas scan (P), kidney scan (K), bone scan (Bo), thyroid scan (T), tumor localization (TL).

Fig. 5. Weighted heart wall doses, over five decades from 1960 to 2010, for four NM diagnostic procedures: cardiac procedures (C), GI bleeding and Meckel's scan (GIB), pancreas scan (P), tumor localization (TL).

Fig. 6. Temporal NM trends in per capita absorbed doses to twelve different target organs, from tumor localization, between 1960 and 2010 (CW= colon wall; RBM= red bone marrow; SW= stomach wall; UBW= urinary bladder wall; HW = heart wall).

Fig. 7.

Temporal NM trends in the weighted doses to twelve different target organs, from cardiac procedures, between 1960 and 2010 (CW= colon wall; RBM= red bone marrow; SW= stomach wall; UBW= urinary bladder wall; HW= heart wall).

ICRP designation and source publication for radiopharmaceuticals used in nuclear medicine procedures during specific time-periods spanning 1960–2010.

Table 1

Radionuclide	Material	ICRP designation	ICRP
¹⁹⁸ Au	Colloid	Colloid	53
⁵¹ Cr	RBC	RBC	53
¹⁸ F	FDG	FDG	106
¹⁸ F	Sodium fluoride	Fluoride	53
⁵⁹ Fe	Citrate	Ion (oral administration)	53
⁶⁷ Ga	Citrate	Ion	80
¹⁹⁷ Hg	Chlormerodrin	Chlormerodrin	53
²⁰³ Hg	Chlormerodrin	Chlormerodrin	53
¹²³ I	Sodium iodide	Sodium iodide	53
¹²⁵ I	HSA	Albumin	53
¹³¹ I	Hippurate	Iodo-hippurate	80
¹³¹ I	HSA	Albumin	53
¹³¹ I	MAA	MAA	53
¹³¹ I	RIHSA	Albumin	53
¹³¹ I	Rose Bengal	Rose Bengal	53
¹³¹ I	Sodium iodide	Sodium iodide	53
¹¹¹ In	Capromab pendetide	Monoclonal antibodies	106
¹¹¹ In	DTPA	DTPA	53
¹¹¹ In	Pentetreotide	Octreotide	106
⁸² Rb	Chloride	Ion	53
⁷⁵ Se	Methionine	Amino acids	106
⁸⁵ Sr	Chloride	Ion	53
⁸⁵ Sr	Nitrate	Ion	53
^{99m} Tc	Albumin colloid	Large colloids	80

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Radionuclide	Material	ICRP designation	ICRP
^{99m} Tc	DISIDA	IDA-derivatives	80
^{99m} Tc	DMSA	DMSA	80
^{99m} Tc	DTPA	DTPA	80
^{99m} Tc	DTPA-aerosol	Aerosols	53
^{99m} Tc	ECD	ECD	106
^{99m} Tc	Glucoheptonate	Glucoheptonate	53
^{99m} Tc	HAM	Albumin microspheres	53
^{99m} Tc	HIDA	IDA-derivatives	80
^{99m} Tc	HMPAO	HMPAO	80
^{99m} Tc	HSA	Albumin	53
^{99m} Tc	IDA	IDA-derivatives	80
^{99m} Tc	MAA	MAA	80
^{99m} Tc	MAG3	MAG3	80
^{99m} Tc	MDP	Phosphates and phosphonates	80
^{99m} Tc	Mebrofenin	IDA-derivatives	80
^{99m} Tc	Pertechnetate	Pertechnetate	80
^{99m} Tc	Pertechnetate	Pertechnetate with blocking agent	80
^{99m} Tc	Polyphosphate	Phosphates and phosphonates	80
^{99m} Tc	Pyrophosphate	Phosphates and phosphonates	80
^{99m} Tc	RBC	RBC	80
^{99m} Tc	SC	Large colloids	80
^{99m} Tc	Sestamibi (1-day)	MIBI	80
^{99m} Tc	Sestamibi (2-day)	MIBI	80
^{99m} Tc	Tetrofosmin	Tetrofosmin	106
²⁰¹ Tl	Chloride	Ion	106
¹³³ Xe		Gas/solution	53

Abbreviations: DISIDA, diisopropyl iminodiacetic acid; DMSA, dimercaptosuccinic acid; DTPA, diethylenetriaminepentaacetic acid; ECD, ethyl cysteine dimer; FDG, fluorodeoxyglucose; HAM, human albumin microspheres; HIDA, N-(2,6-dimethyl-phenyl-carbamoyl-methyl)-iminodiacetic acid; HMPAO, hexamethylpropyleneamineoxime; HSA, human serum albumin; IDA, iminodiacetic acid;

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

MAA, macro aggregated albumin; MAG3, mercaptoacetyl triglycine; MDP, methyl diphosphonate; MIBI, hexakis-2-methoxyisobutylisonitrile; RBC, red blood cells; RHSA, radio-iodinated human serum albumin; SC, sulphur colloids

Table 2

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **breast** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to breast (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.06	0.06	0.06	0.06	0.06	0.06	-	-	-
	⁵¹ Cr-RBC	0.04	0.04	0.07	0.11	0.15	0.15	0.15	0.15	0.15	0.15
	Weighted dose	0.01	0.02	0.04	0.07	0.08	0.07	0.07	0.06	0.05	0.03
Bone marrow scan	¹⁹⁸ Au-colloid	6.1	6.1	6.1	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.47	0.93	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	^{99m} Tc-albumin colloid	-	-	-	-	0.97	0.97	0.97	-	-	-
	Weighted dose	6.1	4.1	1.7	1.2	1.2	1.1	1.2	1.2	1.2	1.2
Bone scan	⁸⁵ Sr-chloride	1.9	1.9	1.9	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	1.9	1.9	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.34	0.45	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	0.39	0.39	0.53	0.53	-	-	-	-	-
	^{99m} Tc-MDP	-	-	0.39	0.53	0.53	0.53	0.53	0.66	0.66	0.66
	Weighted dose	1.9	1.3	0.80	0.53	0.53	0.53	0.53	0.66	0.66	0.66
Brain blood flow	¹³¹ I-RIHSA	8.1	8.1	8.1	8.1	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	0.83	1.0	1.3	1.3	1.3	1.3	-	-	-
	^{99m} Tc-DTPA	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	^{99m} Tc-HMPAO	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5
	^{99m} Tc-ECD	-	-	-	-	-	-	3.7	3.7	3.7	3.7
	¹¹¹ In-DTPA	-	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08
	Weighted dose	8.1	3.7	2.0	1.1	0.67	0.64	0.76	1.2	1.4	1.4

Decade and absorbed dose to breast (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RHSA	8.1	8.1	8.1	8.1	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	0.79	0.94	1.3	1.3	1.3	1.3	-	-	-
	^{99m} Tc-DTPA	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	^{99m} Tc-HMPAO	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5
	^{99m} Tc-ECD	-	-	-	-	-	-	3.7	3.7	3.7	3.7
	¹¹¹ In-DTPA	-	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08
Weighted dose		8.1	3.7	1.9	1.1	0.65	0.62	0.76	1.2	1.4	1.4
Brain scan	¹⁹⁷ Hg-chlormerodrin	0.15	0.15	0.15	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	4.4	4.4	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	0.79	0.94	1.3	1.3	1.3	1.3	-	-	-
	^{99m} Tc-DTPA	-	-	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	^{99m} Tc-glucuheptonate	-	-	-	1.0	1.0	1.0	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5
	^{99m} Tc-ECD	-	-	-	-	-	-	0.66	0.66	0.66	0.66
	²⁰¹ Tl-chloride	-	-	-	-	-	2.7	2.7	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9
Weighted dose		3.6	2.0	0.89	0.93	0.82	1.3	1.4	1.5	1.8	2.0
Cardiac procedures	²⁰¹ Tl-chloride	-	-	2.7	2.7	2.7	2.7	2.7	2.7	3.6	3.6
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	3.8	3.8	3.8	3.8	3.8
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	5.0	5.0	5.0	5.0
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	2.6	2.6	2.6	2.6
	^{99m} Tc-RBC	-	-	2.6	2.6	2.6	2.6	2.6	2.9	3.2	3.2
	^{99m} Tc-pyrophosphate	-	0.39	0.39	0.39	0.39	0.39	0.39	-	-	-
	^{99m} Tc-pertechnetate	-	-	0.67	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	3.4	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	3.3	3.3	3.3	3.3

Decade and absorbed dose to breast (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	0.35
	Weighted dose	<i>a</i>	0.39	1.2	2.4	2.4	2.4	2.8	3.3	3.5	3.5
	^{99m} Tc-RBC	-	2.6	2.6	2.6	2.6	2.6	2.6	2.9	3.2	3.2
	^{99m} Tc-pertechnetate	-	-	0.33	0.33	0.33	0.33	0.67	0.67	0.67	0.67
	Weighted dose	<i>a</i>	2.6	2.5	2.2	2.4	2.3	2.5	2.8	3.2	3.2
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.05	0.05	0.05	0.05	-	-	-	-	-
	^{99m} Tc-HIDA	-	-	-	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	^{99m} Tc-DISIDA	-	-	-	-	-	0.09	0.09	0.09	0.09	0.09
	^{99m} Tc-mebrofenin	-	-	-	0.09	0.09	0.09	0.09	-	-	-
	Weighted dose	<i>a</i>	0.05	0.05	0.06	0.08	0.09	0.09	0.09	0.09	0.09
Iron metabolism	⁵⁹ Fe-citrate	0.28	0.28	0.28	0.28	0.28	0.28	0.28	-	-	-
	Weighted dose	0.28	0.28	0.28	0.28	0.28	0.28	0.28	<i>a</i>	<i>a</i>	<i>a</i>
	Kidney scan	¹³¹ I-hippurate	-	0.01	0.01	0.01	0.01	0.01	0.01	-	-
¹⁹⁷ Hg-chlormerodrin		0.02	0.02	0.03	-	-	-	-	-	-	-
²⁰³ Hg-chlormerodrin		0.63	0.63	-	-	-	-	-	-	-	-
^{99m} Tc-DTPA		-	-	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
^{99m} Tc-DMSA		-	-	-	0.24	0.24	0.24	0.24	0.24	0.24	0.24
^{99m} Tc-glucosheptonate		-	-	0.78	0.78	0.78	0.78	0.65	0.52	0.52	-
^{99m} Tc-MAG3		-	-	-	-	-	-	0.04	0.04	0.04	0.04
Weighted dose		0.36	0.12	0.06	0.23	0.23	0.28	0.13	0.14	0.06	0.05
Liver scan	¹⁹⁸ Au-colloid	0.81	0.81	0.81	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.00	0.05	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.16	0.23	0.39	0.39	0.39	0.39	0.39	0.39	0.39
	^{99m} Tc-IDA	-	-	-	-	0.09	0.09	0.09	0.09	0.09	0.09

Type of examination	Radiopharmaceutical	Decade and absorbed dose to breast (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
		Weighted dose	0.79	0.45	0.29	0.39	0.37	0.33	0.34	0.34	0.33	0.32
Lung perfusion	¹³¹ I-MAA	1.1	1.1	1.1	1.1	-	-	-	-	-	-	
	^{99m} Tc-MAA	-	0.56	0.56	0.74	0.93	0.93	0.93	0.93	0.93	0.93	
	^{99m} Tc-HAM	-	-	0.58	0.58	0.58	0.96	-	-	-	-	
Lung ventilation	Weighted dose	1.1	1.1	0.77	0.72	0.86	0.93	0.93	0.93	0.93	0.93	
	¹³³ Xe	-	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	
Pancreas scan	Weighted dose	<i>a</i>	0.07	0.07	0.07	0.07 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	
	⁷⁵ Se-methionine	9.6	9.6	9.6	9.6	9.6	-	-	-	-	-	
	^{99m} Tc-SC	-	-	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	
Thyroid scan	¹⁸ F-FDG	-	-	-	-	4.9	4.9	4.9	4.9	4.9	4.9	
	Weighted dose	9.6	9.6	7.8	7.8	4.9	3.5	3.8	3.8	3.8	3.8	
	¹³¹ I-sodium iodide	0.10	0.10	0.10	0.15	0.20	0.20	0.20	0.20	0.20	0.20	
Thyroid uptake	¹²³ I-sodium iodide	-	-	0.02	0.02	0.04	0.06	0.06	0.07	0.07	0.07	
	^{99m} Tc-pertechnetate	-	0.13	0.13	0.13	0.33	0.33	0.33	0.40	0.40	0.40	
	Weighted dose	0.10	0.11	0.11	0.12	0.24	0.24	0.22	0.22	0.22	0.20	
Tumor localization	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
	¹²³ I-sodium iodide	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	
	^{99m} Tc-pertechnetate	-	0.03	0.03	0.03	0.03	0.03	0.03	-	-	-	
Tumor localization	Weighted dose	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	
	¹³¹ I-HSA	61	61	61	61	-	-	-	-	-	-	
	⁶⁷ Ga-citrate	-	-	5.2	5.2	5.2	5.2	7.0	7.0	8.7	8.7	
Tumor localization	¹¹¹ In-pentetreotide	-	-	-	-	-	-	2.7	2.7	2.7	2.7	

Decade and absorbed dose to breast (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	1.3	1.3	1.3	
	¹⁸ F-FDG	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9	
Weighted dose		61	61	45	9.1	5.2	5.2	6.6	6.0	5.8	4.8	

^a Procedure not performed.

^b Dose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 3

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **colon wall** in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to colon wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.06	0.06	0.06	0.06	0.06	0.06	-	-	-
	⁵¹ Cr-RBC	0.03	0.03	0.07	0.10	0.13	0.13	0.13	0.13	0.13	0.13
	Weighted dose	0.01	0.02	0.03	0.06	0.07	0.06	0.07	0.05	0.05	0.02
Bone marrow scan	¹⁹⁸ Au-colloid	7.8	7.8	7.8	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.85	1.7	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	^{99m} Tc-albumin colloid	-	-	-	-	1.8	1.8	1.8	-	-	-
	Weighted dose	7.8	5.4	2.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Bone scan	⁸⁵ Sr-chloride	2.9	2.9	2.9	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.9	2.9	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.59	0.79	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	1.5	1.5	2.0	2.0	-	-	-	-	-
	^{99m} Tc-MDP	-	-	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5
	Weighted dose	2.9	2.1	1.7	2.0	2.0	2.0	2.0	2.5	2.5	2.5
Brain blood flow	¹³¹ I-RIHSA	7.6	7.6	7.6	7.6	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	19	23	31	31	31	31	-	-	-
	^{99m} Tc-DTPA	-	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	^{99m} Tc-HMPAO	-	-	-	-	-	12	12	12	12	12
	^{99m} Tc-ECD	-	-	-	-	-	-	1.4	1.4	1.4	1.4
	¹¹¹ In-DTPA	-	-	-	-	0.24	0.24	0.24	0.24	0.24	0.24
Weighted dose	7.6	13	16	14	8.6	7.6	5.2	3.7	2.8	2.7	

Decade and absorbed dose to colon wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	7.6	7.6	7.6	7.6	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	1.7	2.0	2.7	2.7	2.7	2.7	-	-	-
	^{99m} Tc-DTPA	-	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	^{99m} Tc-HMPAO	-	-	-	-	-	12	12	12	12	12
	^{99m} Tc-ECD	-	-	-	-	-	-	1.4	1.4	1.4	1.4
	¹¹¹ In-DTPA	-	-	-	-	0.24	0.24	0.24	0.24	0.24	0.24
Weighted dose		7.6	4.1	2.9	2.6	2.2	2.3	4.4	3.7	2.8	2.7
Brain scan	¹⁹⁷ Hg-chlormerodrin	0.30	0.30	0.30	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	6.9	6.9	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.7	2.0	2.7	2.7	2.7	2.7	-	-	-
	^{99m} Tc-DTPA	-	-	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	^{99m} Tc-glucuheptonate	-	-	-	2.8	2.8	2.8	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	12	12	12	12	12
	^{99m} Tc-ECD	-	-	-	-	-	-	15	15	15	15
	²⁰¹ Tl-chloride	-	-	-	-	-	28	28	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	7.1	7.1	7.1	7.1	7.1
	Weighted dose		5.6	3.3	2.0	2.5	2.5	6.6	8.5	9.8	10
Cardiac procedures	²⁰¹ Tl-chloride	-	-	28	28	28	28	28	28	37	37
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	21	21	21	21	21
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	28	28	28	28
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	20	20	20	20
	^{99m} Tc-RBC	-	-	2.8	2.8	2.8	2.8	2.8	3.1	3.5	3.5
	^{99m} Tc-pyrophosphate	-	1.5	1.5	1.5	1.5	1.5	1.5	-	-	-
	^{99m} Tc-pertechnetate	-	-	15	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	3.3	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	4.8	4.8	4.8	4.8
	Weighted dose		5.6	3.3	2.0	2.5	2.5	6.6	8.5	9.8	10

Decade and absorbed dose to colon wall (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	7.2	
	Weighted dose	<i>a</i>	1.5	9.3	20	19	20	20	21	22	20	
	^{99m} Tc-RBC	-	2.8	2.8	2.8	2.8	2.8	2.8	3.1	3.5	3.5	
	^{99m} Tc-pertechnetate	-	-	7.7	7.7	7.7	7.7	15	15	15	15	
	Weighted dose	<i>a</i>	2.8	3.0	3.6	3.2	3.3	3.3	3.5	3.8	3.8	
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	47	47	47	47	-	-	-	-	-	
	^{99m} Tc-HIDA	-	-	-	14	14	14	14	14	14	14	
	^{99m} Tc-DISIDA	-	-	-	-	-	14	14	14	14	14	
	^{99m} Tc-mebrofenin	-	-	-	14	14	14	14	-	-	-	
	Weighted dose	<i>a</i>	47	47	38	19	14	14	14	14	14	
Iron metabolism	⁵⁹ Fe-citrate	2.1	2.1	2.1	2.1	2.1	2.1	2.1	-	-	-	
	Weighted dose	2.1	2.1	2.1	2.1	2.1	2.1	2.1	<i>a</i>	<i>a</i>	<i>a</i>	
Kidney scan	¹³¹ I-hippurate	-	0.10	0.10	0.10	0.10	0.10	0.10	-	-	-	
	¹⁹⁷ Hg-chlormerodrin	0.04	0.04	0.06	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	0.98	0.98	-	-	-	-	-	-	-	-	
	^{99m} Tc-DTPA	-	-	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	^{99m} Tc-DMSA	-	-	-	0.79	0.79	0.79	0.79	0.79	0.79	0.79	
	^{99m} Tc-glucosheptonate	-	-	2.1	2.1	2.1	2.1	1.7	1.4	1.4	-	
	^{99m} Tc-MAG3	-	-	-	-	-	-	1.3	1.3	1.3	1.3	
	Weighted dose	0.57	0.23	0.28	0.87	0.90	1.0	1.2	1.2	1.2	1.2	
Liver scan	¹⁹⁸ Au-colloid	1.0	1.0	1.0	-	-	-	-	-	-	-	
	¹³¹ I-Rose Bengal	2.1	47	-	-	-	-	-	-	-	-	
	^{99m} Tc-SC	-	0.28	0.42	0.71	0.71	0.71	0.71	0.71	0.71	0.71	
	^{99m} Tc-IDA	-	-	-	-	14	14	14	14	14	14	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to colon wall (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
		Weighted dose	1.1	9.1	0.48	0.71	1.6	3.1	2.8	2.9	3.4
Lung perfusion	¹³¹ I-MAA	0.75	0.75	0.75	0.75	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.22	0.22	0.29	0.36	0.36	0.36	0.36	0.36	0.36
	^{99m} Tc-HAM	-	-	0.26	0.26	0.26	0.44	-	-	-	-
Lung ventilation	Weighted dose	0.75	0.72	0.42	0.30	0.34	0.36	0.36	0.36	0.36	0.36
	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>
Pancreas scan	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>
	⁷⁵ Se-methionine	16	16	16	16	16	-	-	-	-	-
	^{99m} Tc-SC	-	-	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Thyroid scan	¹⁸ F-FDG	-	-	-	-	7.1	7.1	7.1	7.1	7.1	7.1
	Weighted dose	16	16	13	13	7.9	5.2	5.5	5.5	5.5	5.5
	¹³¹ I-sodium iodide	0.09	0.09	0.09	0.14	0.19	0.19	0.19	0.19	0.19	0.19
Thyroid uptake	¹²³ I-sodium iodide	-	-	0.06	0.06	0.11	0.17	0.17	0.22	0.22	0.22
	^{99m} Tc-pertechnetate	-	3.1	3.1	3.1	7.7	7.7	7.7	9.2	9.2	9.2
	Weighted dose	0.09	0.45	1.4	1.9	4.6	4.7	4.2	4.0	3.9	3.5
Tumor localization	¹³¹ I-sodium iodide	0.09	0.09	0.09	0.14	0.19	0.19	0.19	0.19	0.19	0.19
	¹²³ I-sodium iodide	-	-	0.06	0.06	0.11	0.17	0.17	0.22	0.22	0.22
	^{99m} Tc-pertechnetate	-	3.1	3.1	3.1	7.7	7.7	7.7	9.2	9.2	9.2
Tumor localization	Weighted dose	0.01	0.07	0.06	0.11	0.12	0.12	0.06	0.06	0.06	0.07
	¹³¹ I-HSA	57	57	57	57	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	18	18	18	18	23	23	29	29
Tumor localization	¹¹¹ In-pentetreotide	-	-	-	-	-	-	6.4	6.4	6.4	6.4
	Weighted dose	0.01	0.07	0.06	0.11	0.12	0.12	0.06	0.06	0.06	0.07

Decade and absorbed dose to colon wall (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	26	26	26	
	¹⁸ F-FDG	-	-	-	-	-	7.1	7.1	7.1	7.1	7.1	
Weighted dose		57	57	45	20	18	17	21	16	13	7.5	

^a Procedure not performed.

^b Dose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 4

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **kidney** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to kidney (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.09	0.09	0.09	0.09	0.09	0.09	-	-	-
	⁵¹ Cr-RBC	0.08	0.08	0.16	0.24	0.33	0.33	0.33	0.33	0.33	0.33
	Weighted dose	0.03	0.03	0.08	0.15	0.17	0.14	0.16	0.13	0.11	0.06
Bone marrow scan	¹⁹⁸ Au-colloid	17	17	17	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	2.1	4.2	5.3	5.3	5.3	5.3	5.3	5.3	5.3
	^{99m} Tc-albumin colloid	-	-	-	-	4.4	4.4	4.4	-	-	-
	Weighted dose	17	12	6.2	5.3	5.3	5.1	5.2	5.3	5.3	5.3
Bone scan	⁸⁵ Sr-chloride	2.4	2.4	2.4	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.4	2.4	-	-	-	-	-	-	-
	Na ¹⁸ F	-	1.1	1.5	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	4.1	4.1	5.4	5.4	-	-	-	-	-
	^{99m} Tc-MDP	-	-	4.1	5.4	5.4	5.4	5.4	6.8	6.8	6.8
	Weighted dose	2.4	2.4	3.1	5.4	5.4	5.4	5.4	6.8	6.8	6.8
Brain blood flow	¹³¹ I-RIHSA	13	13	13	13	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	2.3	2.8	3.7	3.7	3.7	3.7	-	-	-
	^{99m} Tc-DTPA	-	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	^{99m} Tc-HMPAO	-	-	-	-	-	25	25	25	25	25
	^{99m} Tc-ECD	-	-	-	-	-	-	2.7	2.7	2.7	2.7
	¹¹¹ In-DTPA	-	-	-	-	0.31	0.31	0.31	0.31	0.31	0.31
	Weighted dose	13	6.6	4.3	3.5	2.8	3.1	8.0	6.7	4.9	4.7

Decade and absorbed dose to kidney (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	13	13	13	13	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	2.0	2.4	3.3	3.3	3.3	3.3	-	-	-
	^{99m} Tc-DTPA	-	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	^{99m} Tc-HMPAO	-	-	-	-	-	25	25	25	25	25
	^{99m} Tc-ECD	-	-	-	-	-	-	2.7	2.7	2.7	2.7
	¹¹¹ In-DTPA	-	-	-	-	0.31	0.31	0.31	0.31	0.31	0.31
<hr/>											
Weighted dose		13	6.5	4.1	3.3	2.7	3.0	7.9	6.7	4.9	4.7
<hr/>											
Brain scan	¹⁹⁷ Hg-chlormerodrin	55	55	55	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	494	494	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	2.0	2.4	3.3	3.3	3.3	3.3	-	-	-
	^{99m} Tc-DTPA	-	-	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	^{99m} Tc-glucuheptonate	-	-	-	36	36	36	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	25	25	25	25	25
	^{99m} Tc-ECD	-	-	-	-	-	-	6.4	6.4	6.4	6.4
	²⁰¹ Tl-chloride	-	-	-	-	-	53	53	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	9.4	9.4	9.4	9.4	9.4
	<hr/>										
Weighted dose		411	188	4.0	4.4	6.7	14	13	13	10	10
<hr/>											
Cardiac procedures	²⁰¹ Tl-chloride	-	-	53	53	53	53	53	53	71	71
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	29	29	29	29	29
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	38	38	38	38
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	11	11	11	11
	^{99m} Tc-RBC	-	-	13	13	13	13	13	15	17	17
	^{99m} Tc-pyrophosphate	-	4.1	4.1	4.1	4.1	4.1	4.1	-	-	-
	^{99m} Tc-pertechnetate	-	-	1.85	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	6.0	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	6.3	6.3	6.3	6.3

Decade and absorbed dose to kidney (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	33	
	Weighted dose	<i>a</i>	4.1	10	40	39	39	37	33	33	28	
	^{99m} Tc-RBC	-	13	13	13	13	13	13	15	17	17	
	^{99m} Tc-pertechnetate	-	-	0.93	0.93	0.93	0.93	1.9	1.9	1.9	1.9	
	Weighted dose	<i>a</i>	13	13	11	12	12	13	15	16	16	
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.46	0.46	0.46	0.46	-	-	-	-	-	
	^{99m} Tc-HIDA	-	-	-	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	^{99m} Tc-DISIDA	-	-	-	-	-	1.1	1.1	1.1	1.1	1.1	
	^{99m} Tc-mebrofenin	-	-	-	1.1	1.1	1.1	1.1	-	-	-	
	Weighted dose	<i>a</i>	0.46	0.46	0.64	1.0	1.1	1.1	1.1	1.1	1.1	
Iron metabolism	⁵⁹ Fe-citrate	0.52	0.52	0.52	0.52	0.52	0.52	0.52	-	-	-	
	Weighted dose	0.52	0.52	0.52	0.52	0.52	0.52	0.52	<i>a</i>	<i>a</i>	<i>a</i>	
Kidney scan	¹³¹ I-hippurate	-	0.29	0.29	0.29	0.29	0.29	0.29	-	-	-	
	¹⁹⁷ Hg-chlormerodrin	7.8	7.8	12	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	70	70	-	-	-	-	-	-	-	-	
	^{99m} Tc-DTPA	-	-	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
	^{99m} Tc-DMSA	-	-	-	33	33	33	33	33	33	33	
	^{99m} Tc-glucosheptonate	-	-	27	27	27	27	23	18	18	-	
	^{99m} Tc-MAG3	-	-	-	-	-	-	1.3	1.3	1.3	1.3	
Liver scan	Weighted dose	43	15	2.4	3.9	4.8	7.1	3.4	5.0	2.6	2.5	
	¹⁹⁸ Au-colloid	2.3	2.3	2.3	-	-	-	-	-	-	-	
	¹³¹ I-Rose Bengal	0.02	0.46	-	-	-	-	-	-	-	-	
	^{99m} Tc-SC	-	0.70	1.1	1.8	1.8	1.8	1.8	1.8	1.8	1.8	
	^{99m} Tc-IDA	-	-	-	-	1.1	1.1	1.1	1.1	1.1	1.1	

Decade and absorbed dose to kidney (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Lung perfusion	Weighted dose	2.2	1.4	1.2	1.8	1.7	1.6	1.7	1.7	1.6	1.6
	¹³¹ I-MAA	1.6	1.6	1.6	1.6	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.41	0.41	0.55	0.68	0.68	0.68	0.68	0.68	0.68
	^{99m} Tc-HAM	-	-	0.38	0.38	0.38	0.63	-	-	-	-
Lung ventilation	Weighted dose	1.6	1.5	0.84	0.56	0.63	0.68	0.68	0.68	0.68	0.68
	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.11 <i>b</i>	0.11 <i>b</i>	0.11 <i>b</i>	0.11 <i>b</i>	0.11 <i>b</i>	0.11 <i>b</i>
	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.06 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.08 <i>b</i>	0.09 <i>b</i>	0.10 <i>b</i>
Pancreas scan	⁷⁵ Se-methionine	28	28	28	28	28	-	-	-	-	-
	^{99m} Tc-SC	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	¹⁸ F-FDG	-	-	-	-	9.4	9.4	9.4	9.4	9.4	9.4
	Weighted dose	28	28	23	23	14	7.1	7.5	7.5	7.5	7.5
Thyroid scan	¹³¹ I-sodium iodide	0.11	0.11	0.11	0.16	0.21	0.21	0.21	0.21	0.21	0.21
	¹²³ I-sodium iodide	-	-	0.04	0.04	0.08	0.12	0.12	0.16	0.16	0.16
	^{99m} Tc-pertechnetate	-	0.37	0.37	0.37	0.93	0.93	0.93	1.11	1.11	1.11
	Weighted dose	0.11	0.14	0.22	0.27	0.60	0.62	0.56	0.57	0.56	0.51
Thyroid uptake	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
	¹²³ I-sodium iodide	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	^{99m} Tc-pertechnetate	-	0.09	0.09	0.09	0.09	0.09	0.09	-	-	-
	Weighted dose	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.05	0.05
Tumor localization	¹³¹ I-HSA	98	98	98	98	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	13	13	13	13	18	18	22	22
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	91	91	91	91
	Weighted dose	98	98	13	13	13	13	18	18	22	22

Decade and absorbed dose to kidney (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	148	148	148	
	¹⁸ F-FDG	-	-	-	-	-	9.4	9.4	9.4	9.4	9.4	
Weighted dose		98	98	73	19	13	13	17	22	26	20	

^aProcedure not performed.

^bDose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 5

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **liver** in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to liver (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.08	0.08	0.08	0.08	0.08	0.08	-	-	-
	⁵¹ Cr-RBC	0.09	0.09	0.18	0.27	0.36	0.36	0.36	0.36	0.36	0.36
	Weighted dose	0.03	0.04	0.08	0.16	0.18	0.16	0.17	0.14	0.12	0.06
Bone marrow scan	¹⁹⁸ Au-colloid	455	455	455	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	16	32	39	39	39	39	39	39	39
	^{99m} Tc-albumin colloid	-	-	-	-	33	33	33	-	-	-
	Weighted dose	455	301	95	39	39	38	39	39	39	39
Bone scan	⁸⁵ Sr-chloride	2.2	2.2	2.2	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.2	2.2	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.38	0.51	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	0.67	0.67	0.89	0.89	-	-	-	-	-
	^{99m} Tc-MDP	-	-	0.67	0.89	0.89	0.89	0.89	1.1	1.1	1.1
Weighted dose		2.2	1.5	1.0	0.89	0.89	0.89	0.89	1.1	1.1	1.1
Brain blood flow	¹³¹ I-RIHSA	11	11	11	11	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.8	2.1	2.8	2.8	2.8	2.8	-	-	-
	^{99m} Tc-DTPA	-	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
	^{99m} Tc-HMPAO	-	-	-	-	-	6.4	6.4	6.4	6.4	6.4
	^{99m} Tc-ECD	-	-	-	-	-	-	12	12	12	12
Weighted dose		11	5.3	3.1	2.0	1.3	1.3	2.4	3.7	4.1	4.2
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	11	11	11	11	-	-	-	-	-	-

Decade and absorbed dose to liver (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain scan	^{99m} Tc-pertechnetate w. blocking agent	-	1.2	1.4	1.9	1.9	1.9	1.9	-	-	-
	^{99m} Tc-DTPA	-	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
	^{99m} Tc-HMPAO	-	-	-	-	-	6.4	6.4	6.4	6.4	6.4
	^{99m} Tc-ECD	-	-	-	-	-	-	12	12	12	12
	¹¹¹ In-DTPA	-	-	-	-	0.11	0.11	0.11	0.11	0.11	0.11
	Weighted dose	11	5.0	2.7	1.6	1.0	1.1	2.4	3.7	4.1	4.2
	¹⁹⁷ Hg-chlormerodrin	9.6	9.6	9.6	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	133	133	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.2	1.4	1.9	1.9	1.9	1.9	-	-	-
	^{99m} Tc-DTPA	-	-	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
	^{99m} Tc-glucuheptonate	-	-	-	2.0	2.0	2.0	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	6.4	6.4	6.4	6.4	6.4
Cardiac procedures	^{99m} Tc-ECD	-	-	-	-	-	-	3.7	3.7	3.7	3.7
	²⁰¹ Tl-chloride	-	-	-	-	-	17	17	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	12	12	12	12	12
	Weighted dose	109	50	1.6	1.5	1.4	4.0	4.5	5.1	5.5	5.9
	²⁰¹ Tl-chloride	-	-	17	17	17	17	17	17	22	22
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	10	10	10	10	10
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	14	14	14	14
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	3.7	3.7	3.7	3.7
	^{99m} Tc-RBC	-	-	9.6	9.6	9.6	9.6	9.6	11	12	12
	^{99m} Tc-pyrophosphate	-	0.67	0.67	0.67	0.67	0.67	0.67	-	-	-
	^{99m} Tc-pertechnetate	-	-	1.4	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	5.4	-	-	-	-	-	-
¹⁸ F-FDG	-	-	-	-	-	-	-	7.8	7.8	7.8	
⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	1.8	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to liver (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	Weighted dose	<i>a</i>	0.67	4.5	13	13	13	13	12	12	10
	^{99m} Tc-RBC	-	9.6	9.6	9.6	9.6	9.6	9.6	11	12	12
	^{99m} Tc-pertechnetate	-	-	0.70	0.70	0.70	0.70	1.4	1.4	1.4	1.4
	Weighted dose	<i>a</i>	9.6	9.3	8.1	8.9	8.6	9.3	11	12	12
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	1.7	1.7	1.7	1.7	-	-	-	-	-
	^{99m} Tc-HIDA	-	-	-	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	^{99m} Tc-DISIDA	-	-	-	-	-	2.6	2.6	2.6	2.6	2.6
	^{99m} Tc-mebrofenin	-	-	-	2.6	2.6	2.6	2.6	-	-	-
Iron metabolism	Weighted dose	<i>a</i>	1.7	1.7	1.9	2.4	2.6	2.6	2.6	2.6	2.6
	⁵⁹ Fe-citrate	0.48	0.48	0.48	0.48	0.48	0.48	0.48	-	-	-
Kidney scan	Weighted dose	0.48	0.48	0.48	0.48	0.48	0.48	0.48	<i>a</i>	<i>a</i>	<i>a</i>
	¹³¹ I-hippurate	-	0.02	0.02	0.02	0.02	0.02	0.02	-	-	-
	¹⁹⁷ Hg-chlormerodrin	1.4	1.4	2.1	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	19	19	-	-	-	-	-	-	-	-
	^{99m} Tc-DTPA	-	-	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
	^{99m} Tc-DMSA	-	-	-	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	^{99m} Tc-glucuheptonate	-	-	1.5	1.5	1.5	1.5	1.3	1.0	1.0	-
Liver scan	^{99m} Tc-MAG3	-	-	-	-	-	-	0.11	0.11	0.11	0.11
	Weighted dose	11	3.8	0.41	0.42	0.48	0.61	0.33	0.40	0.20	0.19
	¹⁹⁸ Au-colloid	61	61	61	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.07	1.66	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	5.3	7.9	13	13	13	13	13	13	13
	^{99m} Tc-IDA	-	-	-	-	2.6	2.6	2.6	2.6	2.6	2.6

Type of examination	Radiopharmaceutical	Decade and absorbed dose to liver (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
Lung perfusion	Weighted dose	59	31	13	13	12	11	11	11	11	11	
	¹³¹ I-MAA	23	23	23	23	-	-	-	-	-	-	
	^{99m} Tc-MAA	-	1.8	1.8	2.4	3.0	3.0	3.0	3.0	3.0	3.0	
	^{99m} Tc-HAM	-	-	0.50	0.50	0.50	0.83	-	-	-	-	
	Weighted dose	23	22	9.9	2.9	2.5	2.8	3.0	3.0	3.0	3.0	
Lung ventilation	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
	^{99m} Tc-DTPA aerosol [§]	-	-	-	-	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	
	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	
	⁷⁵ Se-methionine	22	22	22	22	22	-	-	-	-	-	
	^{99m} Tc-SC	-	-	13	13	13	13	13	13	13	13	
Pancreas scan	¹⁸ F-FDG	-	-	-	-	12	12	12	12	12	12	
	Weighted dose	22	22	20	20	17	12	12	12	12	12	
	¹³¹ I-sodium iodide	0.06	0.06	0.06	0.10	0.13	0.13	0.13	0.13	0.13	0.13	
	¹²³ I-sodium iodide	-	-	0.02	0.02	0.05	0.07	0.07	0.09	0.09	0.09	
	^{99m} Tc-pertechnetate	-	0.28	0.28	0.28	0.70	0.70	0.70	0.84	0.84	0.84	
Thyroid scan	Weighted dose	0.06	0.09	0.16	0.20	0.45	0.46	0.42	0.41	0.40	0.37	
	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
	¹²³ I-sodium iodide	-	-	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	^{99m} Tc-pertechnetate	-	0.07	0.07	0.07	0.07	0.07	0.07	-	-	-	
	Weighted dose	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	
Tumor localization	¹³¹ I-HSA	80	80	80	80	-	-	-	-	-	-	
	⁶⁷ Ga-citrate	-	-	13	13	13	13	18	18	22	22	
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	22	22	22	22	

Decade and absorbed dose to liver (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	204	204	204	
	¹⁸ F-FDG	-	-	-	-	-	12	12	12	12	12	
Weighted dose		80	80	61	18	13	13	17	21	21	15	

^a Procedure not performed.

^b Dose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 6

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **lung** in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to lung (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume											
	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.16	0.16	0.16	0.16	0.16	0.16	-	-	-
	⁵¹ Cr-RBC	0.12	0.12	0.24	0.36	0.47	0.47	0.47	0.47	0.47	0.47
	Weighted dose	0.05	0.05	0.11	0.22	0.24	0.21	0.23	0.19	0.16	0.08
Bone marrow scan											
	¹⁹⁸ Au-colloid	10	10	10	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	1.3	2.6	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	^{99m} Tc-albumin colloid	-	-	-	-	2.7	2.7	2.7	-	-	-
	Weighted dose	10	7.0	3.7	3.3	3.3	3.2	3.2	3.3	3.3	3.3
Bone scan											
	⁸⁵ Sr-chloride	2.4	2.4	2.4	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.4	2.4	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.38	0.50	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	0.72	0.72	0.96	0.96	-	-	-	-	-
	^{99m} Tc-MDP	-	-	0.72	0.96	0.96	0.96	0.96	1.2	1.2	1.2
	Weighted dose	2.4	1.6	1.1	0.96	0.96	0.96	0.96	1.2	1.2	1.2
Brain blood flow											
	¹³¹ I-RIHSA	22	22	22	22	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.2	1.4	1.9	1.9	1.9	1.9	-	-	-
	^{99m} Tc-DTPA	-	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
	^{99m} Tc-HMPAO	-	-	-	-	-	8.1	8.1	8.1	8.1	8.1
	^{99m} Tc-ECD	-	-	-	-	-	-	49	49	49	49
	¹¹¹ In-DTPA	-	-	-	-	0.09	0.09	0.09	0.09	0.09	0.09
	Weighted dose	22	9.6	4.4	1.9	0.94	1.0	3.5	10	13	14
Brain blood flow w. blocking agent											
	¹³¹ I-RIHSA	22	22	22	22	-	-	-	-	-	-

Decade and absorbed dose to lung (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	^{99m} Tc-pertechnetate w. blocking agent	-	1.1	1.3	1.7	1.7	1.7	1.7	-	-	-	
	^{99m} Tc-DTPA	-	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	
	^{99m} Tc-HMPAO	-	-	-	-	-	8.1	8.1	8.1	8.1	8.1	
	^{99m} Tc-ECD	-	-	-	-	-	-	49	49	49	49	
	¹¹¹ In-DTPA	-	-	-	-	0.09	0.09	0.09	0.09	0.09	0.09	
	Weighted dose	22	9.5	4.3	1.8	0.89	0.97	3.4	10	13	14	
	Brain scan	¹⁹⁷ Hg-chlormerodrin	0.29	0.29	0.29	-	-	-	-	-	-	-
		²⁰³ Hg-chlormerodrin	6.8	6.8	-	-	-	-	-	-	-	-
		^{99m} Tc-pertechnetate	-	1.1	1.3	1.7	1.7	1.7	1.7	-	-	-
		^{99m} Tc-DTPA	-	-	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
^{99m} Tc-glucuheptonate		-	-	-	1.3	1.3	1.3	-	-	-	-	
^{99m} Tc-HMPAO		-	-	-	-	-	8.1	8.1	8.1	8.1	8.1	
^{99m} Tc-ECD		-	-	-	-	-	-	1.6	1.6	1.6	1.6	
	²⁰¹ Tl-chloride	-	-	-	-	-	12	12	-	-	-	
	¹⁸ F-FDG	-	-	-	-	-	11	11	11	11	11	
	Weighted dose	5.5	3.0	1.2	1.3	1.1	3.6	4.8	5.1	4.9	5.3	
	Cardiac procedures	²⁰¹ Tl-chloride	-	-	12	12	12	12	12	12	16	16
		^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9
		^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	6.5	6.5	6.5	6.5
		^{99m} Tc-tetrofosmin	-	-	-	-	-	-	3.6	3.6	3.6	3.6
		^{99m} Tc-RBC	-	-	13	13	13	13	13	15	17	17
		^{99m} Tc-pyrophosphate	-	0.72	0.72	0.72	0.72	0.72	0.72	-	-	-
		^{99m} Tc-pertechnetate	-	-	0.96	-	-	-	-	-	-	-
^{99m} Tc-HSA		-	-	-	9.6	-	-	-	-	-	-	
¹⁸ F-FDG		-	-	-	-	-	-	7.4	7.4	7.4	7.4	
⁸² Rb-chloride		-	-	-	-	-	-	-	-	-	4.4	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to lung (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
GI bleeding and Meckel's scan	Weighted dose	<i>a</i>	0.72	4.7	11	11	11	9.4	8.4	8.2	6.9	
	^{99m} Tc-RBC	-	13	13	13	13	13	13	15	17	17	
	^{99m} Tc-pertechnetate	-	-	0.48	0.48	0.48	0.48	0.96	0.96	0.96	0.96	
	Weighted dose	<i>a</i>	13	13	11	12	12	13	15	16	16	
	¹³¹ I-Rose Bengal	-	0.08	0.08	0.08	0.08	-	-	-	-	-	
Hepatobiliary scan	^{99m} Tc-HIDA	-	-	-	0.24	0.24	0.24	0.24	0.24	0.24	0.24	
	^{99m} Tc-DISIDA	-	-	-	-	-	0.24	0.24	0.24	0.24	0.24	
	^{99m} Tc-mebrofenin	-	-	-	0.24	0.24	0.24	0.24	-	-	-	
	Weighted dose	<i>a</i>	0.08	0.08	0.12	0.21	0.24	0.24	0.24	0.24	0.24	
	⁵⁹ Fe-citrate	0.74	0.74	0.74	0.74	0.74	0.74	0.74	-	-	-	
Iron metabolism	Weighted dose	0.74	0.74	0.74	0.74	0.74	0.74	0.74	<i>a</i>	<i>a</i>	<i>a</i>	
	¹³¹ I-hippurate	-	0.01	0.01	0.01	0.01	0.01	0.01	-	-	-	
	¹⁹⁷ Hg-chlormerodrin	0.04	0.04	0.06	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	0.96	0.96	-	-	-	-	-	-	-	-	
	^{99m} Tc-DTPA	-	-	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
Kidney scan	^{99m} Tc-DMSA	-	-	-	0.46	0.46	0.46	0.46	0.46	0.46	0.46	
	^{99m} Tc-glucuheptonate	-	-	0.94	0.94	0.94	0.94	0.79	0.63	0.63	-	
	^{99m} Tc-MAG3	-	-	-	-	-	-	0.06	0.06	0.06	0.06	
	Weighted dose	0.56	0.19	0.09	0.31	0.32	0.39	0.19	0.20	0.09	0.08	
	¹⁹⁸ Au-colloid	1.3	1.3	1.3	-	-	-	-	-	-	-	
Liver scan	¹³¹ I-Rose Bengal	0.00	0.08	-	-	-	-	-	-	-	-	
	^{99m} Tc-SC	-	0.44	0.65	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	^{99m} Tc-IDA	-	-	-	-	0.24	0.24	0.24	0.24	0.24	0.24	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to lung (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	Weighted dose	1.3	0.79	0.72	1.1	1.0	0.94	0.96	0.95	0.91	0.90
Lung perfusion	¹³¹ I-MAA	26	26	26	26	-	-	-	-	-	-
	^{99m} Tc-MAA	-	7.3	7.3	9.8	12	12	12	12	12	12
	^{99m} Tc-HAM	-	-	6.4	6.4	6.4	11	-	-	-	-
	Weighted dose	26	24	14	9.8	11	12	12	12	12	12
Lung ventilation	¹³³ Xe	-	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.47 <i>b</i>	0.47 <i>b</i>	0.47 <i>b</i>	0.47 <i>b</i>	0.47 <i>b</i>	0.47 <i>b</i>
	Weighted dose	<i>a</i>	0.43	0.43	0.43	0.43 <i>b</i>	0.44 <i>b</i>	0.44 <i>b</i>	0.44 <i>b</i>	0.46 <i>b</i>	0.46 <i>b</i>
Pancreas scan	⁷⁵ Se-methionine	16	16	16	16	16	-	-	-	-	-
	^{99m} Tc-SC	-	-	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	¹⁸ F-FDG	-	-	-	-	11	11	11	11	11	11
	Weighted dose	16	16	13	13	8.5	8.1	8.6	8.6	8.6	8.6
Thyroid scan	¹³¹ I-sodium iodide	0.13	0.13	0.13	0.20	0.27	0.27	0.27	0.27	0.27	0.27
	¹²³ I-sodium iodide	-	-	0.02	0.02	0.05	0.07	0.07	0.09	0.09	0.09
	^{99m} Tc-pertechnetate	-	0.19	0.19	0.19	0.48	0.48	0.48	0.58	0.58	0.58
	Weighted dose	0.13	0.14	0.16	0.17	0.34	0.34	0.31	0.31	0.30	0.28
Thyroid uptake	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
	¹²³ I-sodium iodide	-	-	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	^{99m} Tc-pertechnetate	-	0.05	0.05	0.05	0.05	0.05	0.05	-	-	-
	Weighted dose	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Tumor localization	¹³¹ I-HSA	167	167	167	167	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	7.0	7.0	7.0	7.0	9.3	9.3	12	12
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	5.1	5.1	5.1	5.1

Decade and absorbed dose to lung (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	26	26	26	
	¹⁸ F-FDG	-	-	-	-	-	11	11	11	11	11	
Weighted dose		167	167	120	18	7.0	7.1	10	10	11	11	

^aProcedure not performed.

^bDose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 7

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **ovary** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to ovary (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.06	0.06	0.06	0.06	0.06	0.06	-	-	-
	⁵¹ Cr-RBC	0.03	0.03	0.06	0.09	0.12	0.12	0.12	0.12	0.12	0.12
Weighted dose		0.01	0.01	0.03	0.06	0.06	0.06	0.06	0.05	0.04	0.02
Bone marrow scan	¹⁹⁸ Au-colloid	4.4	4.4	4.4	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.49	0.98	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	^{99m} Tc-albumin colloid	-	-	-	-	1.0	1.0	1.0	-	-	-
Weighted dose		4.4	3.0	1.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Bone scan	⁸⁵ Sr-chloride	2.8	2.8	2.8	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.8	2.8	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.72	0.96	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	2.0	2.0	2.7	2.7	-	-	-	-	-
	^{99m} Tc-MDP	-	-	2.0	2.7	2.7	2.7	2.7	3.3	3.3	3.3
	Weighted dose	2.8	2.2	2.0	2.7	2.7	2.7	2.7	3.3	3.3	3.3
Brain blood flow	¹³¹ I-RIHSA	7.3	7.3	7.3	7.3	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	4.6	5.6	7.4	7.4	7.4	7.4	-	-	-
	^{99m} Tc-DTPA	-	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	^{99m} Tc-HMPAO	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9
	^{99m} Tc-ECD	-	-	-	-	-	-	1.3	1.3	1.3	1.3
	¹¹¹ In-DTPA	-	-	-	-	0.33	0.33	0.33	0.33	0.33	0.33
Weighted dose		7.3	5.6	5.3	5.0	3.8	3.6	3.1	2.7	2.4	2.4
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	7.3	7.3	7.3	7.3	-	-	-	-	-	-

Decade and absorbed dose to ovary (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	^{99m} Tc-pertechnetate w. blocking agent	-	2.0	2.4	3.2	3.2	3.2	3.2	-	-	-	
	^{99m} Tc-DTPA	-	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	
	^{99m} Tc-HMPAO	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9	
	^{99m} Tc-ECD	-	-	-	-	-	-	1.3	1.3	1.3	1.3	
	¹¹¹ In-DTPA	-	-	-	-	0.33	0.33	0.33	0.33	0.33	0.33	
	Weighted dose	7.3	4.2	3.3	3.3	2.8	2.8	3.0	2.7	2.4	2.4	
	Brain scan	¹⁹⁷ Hg-chlormerodrin	0.24	0.24	0.24	-	-	-	-	-	-	-
		²⁰³ Hg-chlormerodrin	4.9	4.9	-	-	-	-	-	-	-	-
		^{99m} Tc-pertechnetate	-	2.0	2.4	3.2	3.2	3.2	3.2	-	-	-
		^{99m} Tc-DTPA	-	-	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
^{99m} Tc-glucuheptonate		-	-	-	3.4	3.4	3.4	-	-	-	-	
^{99m} Tc-HMPAO		-	-	-	-	-	4.9	4.9	4.9	4.9	4.9	
^{99m} Tc-ECD		-	-	-	-	-	-	5.8	5.8	5.8	5.8	
²⁰¹ Tl-chloride		-	-	-	-	-	13	13	-	-	-	
¹⁸ F-FDG	-	-	-	-	-	7.8	7.8	7.8	7.8	7.8		
Weighted dose	4.0	2.8	2.4	3.2	3.2	3.2	4.8	4.7	5.1	5.5	5.7	
Cardiac procedures	²⁰¹ Tl-chloride	-	-	13	13	13	13	13	13	18	18	
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	9.0	9.0	9.0	9.0	9.0	
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	12	12	12	12	
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	8.5	8.5	8.5	8.5	
	^{99m} Tc-RBC	-	-	2.7	2.7	2.7	2.7	2.7	3.1	3.4	3.4	
	^{99m} Tc-pyrophosphate	-	2.0	2.0	2.0	2.0	2.0	2.0	-	-	-	
	^{99m} Tc-pertechnetate	-	-	3.7	-	-	-	-	-	-	-	
	^{99m} Tc-HSA	-	-	-	3.3	-	-	-	-	-	-	
	¹⁸ F-FDG	-	-	-	-	-	-	5.2	5.2	5.2	5.2	
	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	0.44	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to ovary (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	Weighted dose	<i>a</i>	2.0	3.9	10	9.7	9.9	10	10	10	9.1
	^{99m} Tc-RBC	-	2.7	2.7	2.7	2.7	2.7	2.7	3.1	3.4	3.4
	^{99m} Tc-pertechnetate	-	-	1.9	1.9	1.9	1.9	3.7	3.7	3.7	3.7
	Weighted dose	<i>a</i>	2.7	2.7	2.6	2.7	2.6	2.8	3.1	3.4	3.4
	¹³¹ I-Rose Bengal	-	3.3	3.3	3.3	3.3	-	-	-	-	-
Hepatobiliary scan	^{99m} Tc-HIDA	-	-	-	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	^{99m} Tc-DISIDA	-	-	-	-	-	3.5	3.5	3.5	3.5	3.5
	^{99m} Tc-mebrofenin	-	-	-	3.5	3.5	3.5	3.5	-	-	-
	Weighted dose	<i>a</i>	3.3	3.3	3.4	3.5	3.5	3.5	3.5	3.5	3.5
Iron metabolism	⁵⁹ Fe-citrate	0.59	0.59	0.59	0.59	0.59	0.59	0.59	-	-	-
	Weighted dose	0.59	0.59	0.59	0.59	0.59	0.59	0.59	<i>a</i>	<i>a</i>	<i>a</i>
Kidney scan	¹³¹ I-hippurate	-	0.15	0.15	0.15	0.15	0.15	0.15	-	-	-
	¹⁹⁷ Hg-chlormerodrin	0.03	0.03	0.05	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	0.70	0.70	-	-	-	-	-	-	-	-
	^{99m} Tc-DTPA	-	-	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	^{99m} Tc-DMSA	-	-	-	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	^{99m} Tc-glucuheptonate	-	-	2.6	2.6	2.6	2.6	2.1	1.7	1.7	-
	^{99m} Tc-MAG3	-	-	-	-	-	-	2.0	2.0	2.0	2.0
Liver scan	Weighted dose	0.41	0.19	0.38	1.2	1.2	1.4	1.7	1.7	1.9	1.9
	¹⁹⁸ Au-colloid	0.58	0.58	0.58	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.15	3.32	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.16	0.24	0.41	0.41	0.41	0.41	0.41	0.41	0.41
	^{99m} Tc-IDA	-	-	-	-	3.5	3.5	3.5	3.5	3.5	3.5

Decade and absorbed dose to ovary (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Lung perfusion	Weighted dose	54	54	41	12	9	9	11	10	10	8
	¹³¹ I-MAA	0.49	0.49	0.49	0.49	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.20	0.20	0.27	0.33	0.33	0.33	0.33	0.33	0.33
	^{99m} Tc-HAM	-	-	0.29	0.29	0.29	0.48	-	-	-	-
	Weighted dose	0.49	0.47	0.31	0.28	0.32	0.34	0.33	0.33	0.33	0.33
Lung ventilation	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.09 <i>b</i>	0.09 <i>b</i>	0.09 <i>b</i>	0.09 <i>b</i>	0.09 <i>b</i>	0.09 <i>b</i>
	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.06 <i>b</i>	0.06 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.08 <i>b</i>	0.08 <i>b</i>
	⁷⁵ Se-methionine	20	20	20	20	20	-	-	-	-	-
	^{99m} Tc-SC	-	-	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Pancreas scan	¹⁸ F-FDG	-	-	-	-	7.8	7.8	7.8	7.8	7.8	7.8
	Weighted dose	20	20	16	16	9.6	5.6	5.9	5.9	5.9	5.9
	¹³¹ I-sodium iodide	0.08	0.08	0.08	0.12	0.16	0.16	0.16	0.16	0.16	0.16
	¹²³ I-sodium iodide	-	-	0.04	0.04	0.08	0.12	0.12	0.16	0.16	0.16
	^{99m} Tc-pertechnetate	-	0.74	0.74	0.74	1.9	1.9	1.9	2.2	2.2	2.2
Thyroid scan	Weighted dose	0.08	0.16	0.37	0.49	1.1	1.2	1.1	1.0	1.0	0.90
	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	¹²³ I-sodium iodide	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	^{99m} Tc-pertechnetate	-	0.19	0.19	0.19	0.19	0.19	0.19	-	-	-
	Weighted dose	0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.05	0.05
Thyroid uptake	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	¹²³ I-sodium iodide	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	^{99m} Tc-pertechnetate	-	0.19	0.19	0.19	0.19	0.19	0.19	-	-	-
	Weighted dose	0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.05	0.05
	¹³¹ I-HSA	54	54	54	54	-	-	-	-	-	-
Tumor localization	⁶⁷ Ga-citrate	-	-	9.1	9.1	9.1	9.1	12	12	15	15
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	6.0	6.0	6.0	6.0
	Weighted dose	0.01	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.05	0.05

Decade and absorbed dose to ovary (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	22	22	22	
	¹⁸ F-FDG	-	-	-	-	-	7.8	7.8	7.8	7.8	7.8	
Weighted dose		54	54	41	12	9.1	9.1	11	10	10	7.8	

^aProcedure not performed.

^bDose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 8

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **red bone marrow** in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to red bone marrow (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.10	0.10	0.10	0.10	0.10	0.10	-	-	-
	⁵¹ Cr-RBC	0.05	0.05	0.10	0.16	0.21	0.21	0.21	0.21	0.21	0.21
	Weighted dose	0.02	0.02	0.05	0.10	0.11	0.10	0.10	0.10	0.08	0.07
Bone marrow scan	¹⁹⁸ Au-colloid	105	105	105	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	2.4	4.9	6.1	6.1	6.1	6.1	6.1	6.1	6.1
	^{99m} Tc-albumin colloid	-	-	-	-	5.1	5.1	5.1	-	-	-
	Weighted dose	105	69	20	6.1	6.1	6.0	6.0	6.0	6.1	6.1
Bone scan	⁸⁵ Sr-chloride	6.7	6.7	6.7	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	6.7	6.7	-	-	-	-	-	-	-
	Na ¹⁸ F	-	2.2	3.0	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	5.1	5.1	6.8	6.8	-	-	-	-	-
	^{99m} Tc-MDP	-	-	5.1	6.8	6.8	6.8	6.8	8.5	8.5	8.5
	Weighted dose	6.7	5.3	5.1	6.8	6.8	6.8	6.8	8.5	8.5	8.5
Brain blood flow	¹³¹ I-RIHSA	9.8	9.8	9.8	9.8	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.7	2.0	2.7	2.7	2.7	2.7	-	-	-
	^{99m} Tc-DTPA	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	^{99m} Tc-HMPAO	-	-	-	-	-	2.5	2.5	2.5	2.5	2.5
	^{99m} Tc-ECD	-	-	-	-	-	-	2.4	2.4	2.4	2.4
	¹¹¹ In-DTPA	-	-	-	-	0.17	0.17	0.17	0.17	0.17	0.17
Weighted dose	9.8	4.9	3.0	2.0	1.3	1.3	1.3	1.3	1.4	1.4	

Decade and absorbed dose to red bone marrow (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	9.8	9.8	9.8	9.8	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	1.2	1.4	1.9	1.9	1.9	1.9	-	-	-
	^{99m} Tc-DTPA	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	^{99m} Tc-HMPAO	-	-	-	-	-	2.5	2.5	2.5	2.5	2.5
	^{99m} Tc-ECD	-	-	-	-	-	-	2.4	2.4	2.4	2.4
	¹¹¹ In-DTPA	-	-	-	-	0.17	0.17	0.17	0.17	0.17	0.17
Weighted dose		9.8	4.6	2.6	1.6	1.1	1.1	1.3	1.4	1.4	1.4
Brain scan	¹⁹⁷ Hg-chlormerodrin	1.2	1.2	1.2	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	15	15	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.2	1.4	1.9	1.9	1.9	1.9	-	-	-
	^{99m} Tc-DTPA	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	^{99m} Tc-glucoheptonate	-	-	-	2.9	2.9	2.9	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	2.5	2.5	2.5	2.5	2.5
	^{99m} Tc-ECD	-	-	-	-	-	-	1.8	1.8	1.8	1.8
	²⁰¹ Tl-chloride	-	-	-	-	-	12	12	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1
Weighted dose		13	6.3	1.4	1.5	1.5	3.0	2.3	2.5	2.8	3.0
Cardiac procedures	²⁰¹ Tl-chloride	-	-	12	12	12	12	12	12	16	16
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	5.6	5.6	5.6	5.6	5.6
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	7.4	7.4	7.4	7.4
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	4.3	4.3	4.3	4.3
	^{99m} Tc-RBC	-	-	4.5	4.5	4.5	4.5	4.5	5.1	5.6	5.6
	^{99m} Tc-pyrophosphate	-	5.1	5.1	5.1	5.1	5.1	5.1	-	-	-
	^{99m} Tc-pertechnetate	-	-	1.3	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	5.6	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	4.1	4.1	4.1	4.1

Type of examination	Radiopharmaceutical	Decade and absorbed dose to red bone marrow (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	1.8
	Weighted dose	<i>a</i>	5.1	4.4	10	10	10	8.6	7.4	7.5	6.3
GI bleeding and Meckel's scan	^{99m} Tc-RBC	-	4.5	4.5	4.5	4.5	4.5	4.5	5.1	5.6	5.6
	^{99m} Tc-pertechnetate	-	-	0.67	0.67	0.67	0.67	1.3	1.3	1.3	1.3
	Weighted dose	<i>a</i>	4.5	4.4	3.9	4.2	4.1	4.4	5.0	5.5	5.5
	^{99m} Tc-mebrofenin	-	-	-	0.72	0.72	0.72	0.72	-	-	-
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.70	0.70	0.70	0.70	-	-	-	-	-
	^{99m} Tc-HIDA	-	-	-	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	^{99m} Tc-DISIDA	-	-	-	-	-	0.72	0.72	0.72	0.72	0.72
	Weighted dose	<i>a</i>	0.70	0.70	0.70	0.72	0.72	0.72	0.72	0.72	0.72
Iron metabolism	⁵⁹ Fe-citrate	0.56	0.56	0.56	0.56	0.56	0.56	0.56	-	-	-
	Weighted dose	0.56	0.56	0.56	0.56	0.56	0.56	0.56	<i>a</i>	<i>a</i>	<i>a</i>
Kidney scan	¹³¹ I-hippurate	-	0.04	0.04	0.04	0.04	0.04	0.04	-	-	-
	¹⁹⁷ Hg-chlormerodrin	0.18	0.18	0.27	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	2.2	2.2	-	-	-	-	-	-	-	-
	^{99m} Tc-DTPA	-	-	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
	^{99m} Tc-DMSA	-	-	-	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	^{99m} Tc-glucosheptonate	-	-	2.2	2.2	2.2	2.2	1.8	1.4	1.4	-
	Weighted dose	-	-	-	-	-	-	0.34	0.34	0.34	0.34
Liver scan	¹⁸⁸ Au-colloid	14	14	14	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.03	0.70	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.81	1.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	^{99m} Tc-IDA	-	-	-	-	0.72	0.72	0.72	0.72	0.72	0.72
	Weighted dose	1.3	0.46	0.17	0.52	0.52	0.66	0.43	0.48	0.39	0.36

Type of examination	Radiopharmaceutical	Decade and absorbed dose to red bone marrow (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Lung perfusion	Weighted dose	14	7.0	2.4	2.0	1.9	1.8	1.8	1.8	1.8	1.7
	¹³¹ I-MAA	0.80	0.80	0.80	0.80	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.36	0.36	0.47	0.59	0.59	0.59	0.59	0.59	0.59
	^{99m} Tc-HAM	-	-	0.51	0.51	0.51	0.85	-	-	-	-
Lung ventilation	Weighted dose	0.80	0.77	0.53	0.49	0.58	0.61	0.59	0.59	0.59	0.59
	¹³³ Xe	-	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>
	Weighted dose	<i>a</i>	0.07	0.07	0.07	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>	0.07 <i>b</i>
Pancreas scan	⁷⁵ Se-methionine	14	14	14	14	14	-	-	-	-	-
	^{99m} Tc-SC	-	-	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	¹⁸ F-FDG	-	-	-	-	6.1	6.1	6.1	6.1	6.1	6.1
	Weighted dose	14	14	12	12	7.6	4.9	5.1	5.1	5.1	5.1
Thyroid scan	¹³¹ I-sodium iodide	0.13	0.13	0.13	0.20	0.26	0.26	0.26	0.26	0.26	0.26
	¹²³ I-sodium iodide	-	-	0.04	0.04	0.07	0.11	0.11	0.15	0.15	0.15
	^{99m} Tc-pertechnetate	-	0.27	0.27	0.27	0.67	0.67	0.67	0.80	0.80	0.80
	Weighted dose	0.13	0.15	0.19	0.21	0.46	0.46	0.42	0.43	0.42	0.39
Thyroid uptake	¹³¹ I-sodium iodide	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
	¹²³ I-sodium iodide	-	-	-	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	^{99m} Tc-pertechnetate	-	0.07	0.07	0.07	0.07	0.07	0.07	-	-	-
	Weighted dose	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05
Tumor localization	¹³¹ I-HSA	73	73	73	73	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	23	23	23	23	31	31	39	39
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	4.9	4.9	4.9	4.9

Decade and absorbed dose to red bone marrow (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	76	76	76
	¹⁸ F-FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1
Weighted dose		73	73	59	27	23	23	27	21	16	7.0

^a Procedure not performed.

^b Dose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 9

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **stomach wall** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to stomach wall (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.06	0.06	0.06	0.06	0.06	0.06	-	-	-
	⁵¹ Cr-RBC	0.05	0.05	0.10	0.16	0.21	0.21	0.21	0.21	0.21	0.21
	Weighted dose	0.02	0.02	0.05	0.10	0.11	0.09	0.10	0.08	0.07	0.04
Bone marrow scan	¹⁹⁸ Au-colloid	12	12	12	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	1.4	2.8	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	^{99m} Tc-albumin colloid	-	-	-	-	3.0	3.0	3.0	-	-	-
	Weighted dose	12	8.1	4.2	3.6	3.5	3.5	3.5	3.6	3.6	3.6
Bone scan	⁸⁵ Sr-chloride	2.0	2.0	2.0	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.0	2.0	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.37	0.50	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	0.67	0.67	0.89	0.89	-	-	-	-	-
	^{99m} Tc-MDP	-	-	0.67	0.89	0.89	0.89	0.89	1.1	1.1	1.1
	Weighted dose	2.0	1.4	1.0	0.89	0.89	0.89	0.89	1.1	1.1	1.1
Brain blood flow	¹³¹ I-RIHSA	7.8	7.8	7.8	7.8	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	12	14	19	19	19	19	-	-	-
	^{99m} Tc-DTPA	-	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	^{99m} Tc-HMPAO	-	-	-	-	-	4.7	4.7	4.7	4.7	4.7
	^{99m} Tc-ECD	-	-	-	-	-	-	2.7	2.7	2.7	2.7
	¹¹¹ In-DTPA	-	-	-	-	0.12	0.12	0.12	0.12	0.12	0.12
	Weighted dose	7.8	9.6	10	8.8	5.1	4.4	2.3	1.8	1.7	1.7

Decade and absorbed dose to stomach wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	7.8	7.8	7.8	7.8	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	1.3	1.5	2.0	2.0	2.0	2.0	-	-	-
	^{99m} Tc-DTPA	-	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	^{99m} Tc-HMPAO	-	-	-	-	-	4.7	4.7	4.7	4.7	4.7
	^{99m} Tc-ECD	-	-	-	-	-	-	2.7	2.7	2.7	2.7
	¹¹¹ In-DTPA	-	-	-	-	0.12	0.12	0.12	0.12	0.12	0.12
Weighted dose		7.8	3.9	2.3	1.6	1.1	1.1	1.8	1.8	1.7	1.7
Brain scan	¹⁹⁷ Hg-chlormerodrin	0.39	0.39	0.39	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	8.6	8.6	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.3	1.5	2.0	2.0	2.0	2.0	-	-	-
	^{99m} Tc-DTPA	-	-	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	^{99m} Tc-glucuheptonate	-	-	-	2.0	2.0	2.0	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	4.7	4.7	4.7	4.7	4.7
	^{99m} Tc-ECD	-	-	-	-	-	-	2.0	2.0	2.0	2.0
	²⁰¹ Tl-chloride	-	-	-	-	-	12	12	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1
	Weighted dose		7.0	3.7	1.4	1.6	1.4	3.2	3.2	3.3	3.3
Cardiac procedures	²⁰¹ Tl-chloride	-	-	12	12	12	12	12	12	16	16
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	6.5	6.5	6.5	6.5	6.5
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	8.7	8.7	8.7	8.7
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	5.1	5.1	5.1	5.1
	^{99m} Tc-RBC	-	-	3.4	3.4	3.4	3.4	3.4	3.8	4.3	4.3
	^{99m} Tc-pyrophosphate	-	0.67	0.67	0.67	0.67	0.67	0.67	-	-	-
	^{99m} Tc-pertechnetate	-	-	9.6	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	3.8	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	4.1	4.1	4.1	4.1

Type of examination	Radiopharmaceutical	Decade and absorbed dose to stomach wall (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	7.0	
	Weighted dose	<i>a</i>	0.67	5.6	9.3	8.9	9.0	8.5	7.8	8.0	7.0	
	^{99m} Tc-RBC	-	3.4	3.4	3.4	3.4	3.4	3.4	3.8	4.3	4.3	
	^{99m} Tc-pertechnetate	-	-	4.8	4.8	4.8	4.8	9.6	9.6	9.6	9.6	
	Weighted dose	<i>a</i>	3.4	3.5	3.6	3.5	3.6	3.7	4.0	4.4	4.4	
	Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.61	0.61	0.61	0.61	-	-	-	-	-
		^{99m} Tc-HIDA	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		^{99m} Tc-DISIDA	-	-	-	-	-	1.0	1.0	1.0	1.0	1.0
		^{99m} Tc-mebrofenin	-	-	-	1.0	1.0	1.0	1.0	-	-	-
	Iron metabolism	Weighted dose	<i>a</i>	0.61	0.61	0.73	0.97	1.0	1.0	1.0	1.0	1.0
⁵⁹ Fe-citrate		0.37	0.37	0.37	0.37	0.37	0.37	0.37	-	-	-	
Kidney scan	Weighted dose	0.37	0.37	0.37	0.37	0.37	0.37	0.37	<i>a</i>	<i>a</i>	<i>a</i>	
	¹³¹ I-hippurate	-	0.02	0.02	0.02	0.02	0.02	0.02	-	-	-	
	¹⁹⁷ Hg-chlormerodrin	0.06	0.06	0.08	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	1.2	1.2	-	-	-	-	-	-	-	-	
	^{99m} Tc-DTPA	-	-	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
	^{99m} Tc-DMSA	-	-	-	0.96	0.96	0.96	0.96	0.96	0.96	0.96	
	^{99m} Tc-glucosheptonate	-	-	1.5	1.5	1.5	1.5	1.3	1.0	1.0	-	
	^{99m} Tc-MAG3	-	-	-	-	-	-	0.14	0.14	0.14	0.14	
	Weighted dose	0.71	0.24	0.12	0.43	0.46	0.57	0.32	0.35	0.20	0.19	
	Liver scan	¹⁹⁸ Au-colloid	1.6	1.6	1.6	-	-	-	-	-	-	-
¹³¹ I-Rose Bengal		0.03	0.61	-	-	-	-	-	-	-	-	
^{99m} Tc-SC		-	0.47	0.71	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
^{99m} Tc-IDA		-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to stomach wall (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
		Weighted dose	1.5	1.0	0.79	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Lung perfusion	¹³¹ I-MAA	1.0	1.0	1.0	1.0	-	-	-	-	-	-	
	^{99m} Tc-MAA	-	0.41	0.41	0.55	0.68	0.68	0.68	0.68	0.68	0.68	
	^{99m} Tc-HAM	-	-	0.42	0.42	0.42	0.70	-	-	-	-	
	Weighted dose	1.0	0.99	0.65	0.54	0.63	0.69	0.68	0.68	0.68	0.68	
Lung ventilation	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	
	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	
	Pancreas scan	⁷⁵ Se-methionine	17	17	17	17	17	-	-	-	-	-
^{99m} Tc-SC		-	-	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
¹⁸ F-FDG		-	-	-	-	6.1	6.1	6.1	6.1	6.1	6.1	
Weighted dose		17	17	14	14	8.5	4.6	4.9	4.9	4.9	4.9	
Thyroid scan	¹³¹ I-sodium iodide	0.85	0.85	0.85	1.3	1.7	1.7	1.7	1.7	1.7	1.7	
	¹²³ I-sodium iodide	-	-	0.25	0.25	0.50	0.75	0.75	1.0	1.0	1.0	
	^{99m} Tc-pertechnetate	-	1.9	1.9	1.9	4.8	4.8	4.8	5.8	5.8	5.8	
	Weighted dose	0.85	0.98	1.3	1.5	3.3	3.3	3.0	3.1	3.0	2.8	
Thyroid uptake	¹³¹ I-sodium iodide	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.12	0.12	
	¹²³ I-sodium iodide	-	-	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
	^{99m} Tc-pertechnetate	-	0.48	0.48	0.48	0.48	0.48	0.48	-	-	-	
	Weighted dose	0.09	0.12	0.11	0.18	0.22	0.22	0.25	0.27	0.32	0.33	
Tumor localization	¹³¹ I-HSA	59	59	59	59	-	-	-	-	-	-	
	⁶⁷ Ga-citrate	-	-	7.7	7.7	7.7	7.7	10	10	13	13	
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	9.5	9.5	9.5	9.5	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to stomach wall (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	^{111}In -capromab pendetide	-	-	-	-	-	-	-	30	30	30
	^{18}F -FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1
Weighted dose		59	59	44	11	7.7	7.6	10	9.0	8.8	6.8

^a Procedure not performed.

^b Dose calculations for a $^{99\text{m}}\text{Tc}$ -DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 10

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **testis** in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to testis (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.04	0.04	0.04	0.04	0.04	0.04	-	-	-
	⁵¹ Cr-RBC	0.02	0.02	0.05	0.07	0.09	0.09	0.09	0.09	0.09	0.09
Weighted dose		0.01	0.01	0.02	0.05	0.05	0.04	0.05	0.04	0.03	0.02
Bone marrow scan	¹⁹⁸ Au-colloid	1.7	1.7	1.7	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.12	0.25	0.31	0.31	0.31	0.31	0.31	0.31	0.31
	^{99m} Tc-albumin colloid	-	-	-	-	0.26	0.26	0.26	-	-	-
Weighted dose		1.7	1.2	0.47	0.31	0.31	0.30	0.31	0.31	0.31	0.31
Bone scan	⁸⁵ Sr-chloride	2.1	2.1	2.1	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.1	2.1	-	-	-	-	-	-	-
	Na ¹⁸ F	-	0.61	0.81	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	1.3	1.3	1.8	1.8	-	-	-	-	-
	^{99m} Tc-MDP	-	-	1.3	1.8	1.8	1.8	1.8	2.2	2.2	2.2
Weighted dose		2.1	1.6	1.4	1.8	1.8	1.8	1.8	2.2	2.2	2.2
Brain blood flow	¹³¹ I-RIHSA	6.8	6.8	6.8	6.8	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.3	1.6	2.1	2.1	2.1	2.1	-	-	-
	^{99m} Tc-DTPA	-	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	^{99m} Tc-HMPAO	-	-	-	-	-	1.8	1.8	1.8	1.8	1.8
	^{99m} Tc-ECD	-	-	-	-	-	-	0.81	0.81	0.81	0.81
	¹¹¹ In-DTPA	-	-	-	-	0.22	0.22	0.22	0.22	0.22	0.22
Weighted dose		6.8	3.6	2.5	2.3	1.9	1.9	1.6	1.5	1.5	1.5
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	6.8	6.8	6.8	6.8	-	-	-	-	-	-

Decade and absorbed dose to testis (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
Brain scan	^{99m} Tc-pertechnetate w. blocking agent	-	1.4	1.7	2.2	2.2	2.2	2.2	-	-	-	
	^{99m} Tc-DTPA	-	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	
	^{99m} Tc-HMPAO	-	-	-	-	-	1.8	1.8	1.8	1.8	1.8	
	^{99m} Tc-ECD	-	-	-	-	-	-	0.81	0.81	0.81	0.81	
	¹¹¹ In-DTPA	-	-	-	-	0.22	0.22	0.22	0.22	0.22	0.22	
	Weighted dose	6.8	3.6	2.5	2.3	2.0	1.9	1.6	1.5	1.5	1.5	
	¹⁹⁷ Hg-chlormerodrin	0.17	0.17	0.17	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	3.1	3.1	-	-	-	-	-	-	-	-	
	^{99m} Tc-pertechnetate	-	1.4	1.7	2.2	2.2	2.2	2.2	-	-	-	
	^{99m} Tc-DTPA	-	-	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	
Cardiac procedures	^{99m} Tc-glucuheptonate	-	-	-	2.1	2.1	2.1	-	-	-	-	
	^{99m} Tc-HMPAO	-	-	-	-	-	1.8	1.8	1.8	1.8	1.8	
	^{99m} Tc-ECD	-	-	-	-	-	-	2.0	2.0	2.0	2.0	
	²⁰¹ Tl-chloride	-	-	-	-	-	20	20	-	-	-	
	¹⁸ F-FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1	
	Weighted dose	2.6	1.8	1.7	2.2	2.2	4.2	2.5	2.6	2.9	3.1	
	²⁰¹ Tl-chloride	-	-	20	20	20	20	20	20	27	27	
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	4.1	4.1	4.1	4.1	4.1	
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	5.5	5.5	5.5	5.5	
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	3.8	3.8	3.8	3.8	
	^{99m} Tc-RBC	-	-	1.7	1.7	1.7	1.7	1.7	1.9	2.1	2.1	
	^{99m} Tc-pyrophosphate	-	1.3	1.3	1.3	1.3	1.3	1.3	-	-	-	
	^{99m} Tc-pertechnetate	-	-	1.0	-	-	-	-	-	-	-	
	^{99m} Tc-HSA	-	-	-	2.1	-	-	-	-	-	-	
	¹⁸ F-FDG	-	-	-	-	-	-	4.1	4.1	4.1	4.1	
	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	0.24	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to testis (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	Weighted dose	<i>a</i>	1.3	3.2	1.4	1.4	1.4	1.1	8.6	8.2	5.9
	^{99m} Tc-RBC	-	1.7	1.7	1.7	1.7	1.7	1.7	1.9	2.1	2.1
	^{99m} Tc-pertechnetate	-	-	0.52	0.52	0.52	0.52	1.0	1.0	1.0	1.0
	Weighted dose	<i>a</i>	1.7	1.7	1.5	1.6	1.6	1.7	1.9	2.1	2.1
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.30	0.30	0.30	0.30	-	-	-	-	-
	^{99m} Tc-HIDA	-	-	-	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	^{99m} Tc-DISIDA	-	-	-	-	-	0.28	0.28	0.28	0.28	0.28
	^{99m} Tc-mebrofenin	-	-	-	0.28	0.28	0.28	0.28	-	-	-
Iron metabolism	Weighted dose	<i>a</i>	0.30	0.30	0.29	0.28	0.28	0.28	0.28	0.28	0.28
	⁵⁹ Fe-citrate	0.22	0.22	0.22	0.22	0.22	0.22	0.22	-	-	-
	Weighted dose	0.22	0.22	0.22	0.22	0.22	0.22	0.22	<i>a</i>	<i>a</i>	<i>a</i>
Kidney scan	¹³¹ I-hippurate	-	0.11	0.11	0.11	0.11	0.11	0.11	-	-	-
	¹⁹⁷ Hg-chlormerodrin	0.02	0.02	0.04	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	0.44	0.44	-	-	-	-	-	-	-	-
	^{99m} Tc-DTPA	-	-	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	^{99m} Tc-DMSA	-	-	-	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	^{99m} Tc-glucuheptonate	-	-	1.6	1.6	1.6	1.6	1.3	1.1	1.1	-
	^{99m} Tc-MAG3	-	-	-	-	-	-	1.4	1.4	1.4	1.4
Liver scan	Weighted dose	0.26	0.13	0.27	0.79	0.81	0.91	1.2	1.2	1.3	1.3
	¹⁹⁸ Au-colloid	0.23	0.23	0.23	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.01	0.30	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.04	0.06	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	^{99m} Tc-IDA	-	-	-	-	0.28	0.28	0.28	0.28	0.28	0.28

Type of examination	Radiopharmaceutical	Decade and absorbed dose to testis (mGy)										
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
Lung perfusion	Weighted dose	0.22	0.18	0.08	0.10	0.12	0.13	0.13	0.13	0.14	0.14	
	¹³¹ I-MAA	0.38	0.38	0.38	0.38	-	-	-	-	-	-	
	^{99m} Tc-MAA	-	0.12	0.12	0.16	0.20	0.20	0.20	0.20	0.20	0.20	
	^{99m} Tc-HAM	-	-	0.19	0.19	0.19	0.31	-	-	-	-	
Lung ventilation	Weighted dose	0.38	0.36	0.22	0.18	0.20	0.21	0.20	0.20	0.20	0.20	
	¹³³ Xe	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	
	Weighted dose	<i>a</i>	0.05	0.05	0.05	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	0.06 <i>b</i>	
Pancreas scan	⁷⁵ Se-methionine	17	17	17	17	17	-	-	-	-	-	
	^{99m} Tc-SC	-	-	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
	¹⁸ F-FDG	-	-	-	-	6.1	6.1	6.1	6.1	6.1	6.1	
	Weighted dose	17	17	14	14	8.0	4.3	4.6	4.6	4.6	4.6	
Thyroid scan	¹³¹ I-sodium iodide	0.05	0.05	0.05	0.08	0.10	0.10	0.10	0.10	0.10	0.10	
	¹²³ I-sodium iodide	-	-	0.02	0.02	0.04	0.06	0.06	0.08	0.08	0.08	
	^{99m} Tc-pertechnetate	-	0.21	0.21	0.21	0.52	0.52	0.52	0.62	0.62	0.62	
	Weighted dose	0.05	0.07	0.12	0.15	0.33	0.34	0.31	0.31	0.30	0.27	
Thyroid uptake	¹³¹ I-sodium iodide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	
	¹²³ I-sodium iodide	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	
	^{99m} Tc-pertechnetate	-	0.05	0.05	0.05	0.05	0.05	0.05	-	-	-	
	Weighted dose	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	
Tumor localization	¹³¹ I-HSA	51	51	51	51	-	-	-	-	-	-	
	⁶⁷ Ga-citrate	-	-	6.2	6.2	6.2	6.2	8.3	8.3	10.4	10.4	
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	3.8	3.8	3.8	3.8	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to testis (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	^{111}In -capromab pendetide	-	-	-	-	-	-	-	8.9	8.9	8.9
	^{18}F -FDG	-	-	-	-	-	6.1	6.1	6.1	6.1	6.1
	Weighted dose	51	51	38	9.4	6.2	6.2	7.9	7.2	7.0	5.9

^a Procedure not performed.

^b Dose calculations for a $^{99\text{m}}\text{Tc}$ -DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 11

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **thyroid** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to thyroid (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	^{131}I -RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	^{125}I -HSA	-	0.07	0.07	0.07	0.07	0.07	0.07	-	-	-
	^{51}Cr -RBC	0.04	0.04	0.09	0.13	0.18	0.18	0.18	0.18	0.18	0.18
Weighted dose		0.02	0.02	0.04	0.08	0.09	0.08	0.09	0.07	0.06	0.03
Bone marrow scan	^{198}Au -colloid	2.2	2.2	2.2	-	-	-	-	-	-	-
	$^{99\text{m}}\text{Tc}$ -SC	-	0.21	0.41	0.52	0.52	0.52	0.52	0.52	0.52	0.52
	$^{99\text{m}}\text{Tc}$ -albumin colloid	-	-	-	-	0.43	0.43	0.43	-	-	-
Weighted dose		2.2	1.5	0.68	0.52	0.51	0.50	0.51	0.52	0.52	0.52
Bone scan	^{85}Sr -chloride	2.5	2.5	2.5	-	-	-	-	-	-	-
	^{85}Sr -nitrate	-	2.5	2.5	-	-	-	-	-	-	-
	Na^{18}F	-	0.38	0.50	-	-	-	-	-	-	-
	$^{99\text{m}}\text{Tc}$ -polyphosphate	-	0.72	0.72	0.96	0.96	-	-	-	-	-
	$^{99\text{m}}\text{Tc}$ -MDP	-	-	0.72	0.96	0.96	0.96	0.96	1.2	1.2	1.2
Weighted dose		2.5	1.7	1.2	0.96	0.96	0.96	0.96	1.2	1.2	1.2
Brain blood flow	^{131}I -RIHSA	10	10	10	10	-	-	-	-	-	-
	$^{99\text{m}}\text{Tc}$ -pertechnetate	-	10	12	16	16	16	16	-	-	-
	$^{99\text{m}}\text{Tc}$ -DTPA	-	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
	$^{99\text{m}}\text{Tc}$ -HMPAO	-	-	-	-	-	19	19	19	19	19
	$^{99\text{m}}\text{Tc}$ -ECD	-	-	-	-	-	-	1.9	1.9	1.9	1.9
Weighted dose		10	9.6	9.4	7.6	4.2	4.0	5.7	4.3	2.9	2.8

Decade and absorbed dose to thyroid (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	10	10	10	10	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	1.1	1.3	1.8	1.8	1.8	1.8	-	-	-
	^{99m} Tc-DTPA	-	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
	^{99m} Tc-HMPAO	-	-	-	-	-	19	19	19	19	19
	^{99m} Tc-ECD	-	-	-	-	-	-	1.9	1.9	1.9	1.9
	¹¹¹ In-DTPA	-	-	-	-	0.08	0.08	0.08	0.08	0.08	0.08
Weighted dose		10	4.8	2.6	1.5	0.9	1.2	5.3	4.3	2.9	2.8
Brain scan	¹⁹⁷ Hg-chlormerodrin	0.08	0.08	0.08	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	2.6	2.6	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	1.1	1.3	1.8	1.8	1.8	1.8	-	-	-
	^{99m} Tc-DTPA	-	-	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
	^{99m} Tc-glucuheptonate	-	-	-	0.81	0.81	0.81	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	19	19	19	19	19
	^{99m} Tc-ECD	-	-	-	-	-	-	4.5	4.5	4.5	4.5
	²⁰¹ Tl-chloride	-	-	-	-	-	24	24	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	5.6	5.6	5.6	5.6	5.6
	Weighted dose		2.1	1.5	1.2	1.3	1.1	6.0	9.1	8.9	6.9
Cardiac procedures	²⁰¹ Tl-chloride	-	-	24	24	24	24	24	24	33	33
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	4.9	4.9	4.9	4.9	4.9
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	6.5	6.5	6.5	6.5
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	5.2	5.2	5.2	5.2
	^{99m} Tc-RBC	-	-	4.2	4.2	4.2	4.2	4.2	4.7	5.3	5.3
	^{99m} Tc-pyrophosphate	-	0.72	0.72	0.72	0.72	0.72	0.72	-	-	-
	^{99m} Tc-pertechnetate	-	-	1.0	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	3.6	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	3.7	3.7	3.7	3.7

Decade and absorbed dose to thyroid (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	70	
	Weighted dose	<i>a</i>	0.72	4.0	18	17	17	14	11	10	8.2	
	^{99m} Tc-RBC	-	4.2	4.2	4.2	4.2	4.2	4.2	4.7	5.3	5.3	
	^{99m} Tc-pertechnetate	-	-	4.1	4.1	4.1	4.1	8.1	8.1	8.1	8.1	
	Weighted dose	<i>a</i>	4.2	4.2	4.2	4.2	4.2	4.4	4.8	5.4	5.4	
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	0.01	0.01	0.01	0.01	-	-	-	-	-	
	^{99m} Tc-HIDA	-	-	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
	^{99m} Tc-DISIDA	-	-	-	-	-	0.03	0.03	0.03	0.03	0.03	
	^{99m} Tc-mebrofenin	-	-	-	0.03	0.03	0.03	0.03	-	-	-	
	Weighted dose	<i>a</i>	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	
Iron metabolism	⁵⁹ Fe-citrate	0.31	0.31	0.31	0.31	0.31	0.31	0.31	-	-	-	
	Weighted dose	0.31	0.31	0.31	0.31	0.31	0.31	0.31	<i>a</i>	<i>a</i>	<i>a</i>	
Kidney scan	¹³¹ I-hippurate	-	0.01	0.01	0.01	0.01	0.01	0.01	-	-	-	
	¹⁹⁷ Hg-chlormerodrin	0.01	0.01	0.02	-	-	-	-	-	-	-	
	²⁰³ Hg-chlormerodrin	0.37	0.37	-	-	-	-	-	-	-	-	
	^{99m} Tc-DTPA	-	-	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
	^{99m} Tc-DMSA	-	-	-	0.28	0.28	0.28	0.28	0.28	0.28	0.28	
	^{99m} Tc-glucosheptonate	-	-	0.61	0.61	0.61	0.61	0.51	0.41	0.41	-	
	^{99m} Tc-MAG3	-	-	-	-	-	-	0.05	0.05	0.05	0.05	
	Weighted dose	0.21	0.07	0.08	0.27	0.28	0.33	0.18	0.17	0.08	0.07	
Liver scan	¹⁹⁸ Au-colloid	0.30	0.30	0.30	-	-	-	-	-	-	-	
	¹³¹ I-Rose Bengal	0.00	0.01	-	-	-	-	-	-	-	-	
	^{99m} Tc-SC	-	0.07	0.10	0.17	0.17	0.17	0.17	0.17	0.17	0.17	
	^{99m} Tc-IDA	-	-	-	-	0.03	0.03	0.03	0.03	0.03	0.03	

Type of examination	Radiopharmaceutical	Decade and absorbed dose to thyroid (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	Weighted dose	0.29	0.17	0.12	0.17	0.16	0.15	0.15	0.15	0.14	0.14
Lung perfusion	¹³¹ I-MAA	0.49	0.49	0.49	0.49	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.28	0.28	0.37	0.46	0.46	0.46	0.46	0.46	0.46
	^{99m} Tc-HAM	-	-	0.24	0.24	0.24	0.41	-	-	-	-
	Weighted dose	0.49	0.47	0.36	0.35	0.42	0.46	0.46	0.46	0.46	0.46
Lung ventilation	¹³³ Xe	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	^{99m} Tc-DTPA aerosol	-	-	-	-	0.03 <i>b</i>	0.03 <i>b</i>	0.03 <i>b</i>	0.03 <i>b</i>	0.03 <i>b</i>	0.03 <i>b</i>
	Weighted dose	<i>a</i>	0.05	0.05	0.05	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.05 <i>b</i>	0.04 <i>b</i>	0.04 <i>b</i>
Pancreas scan	⁷⁵ Se-methionine	21	21	21	21	21	-	-	-	-	-
	^{99m} Tc-SC	-	-	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	¹⁸ F-FDG	-	-	-	-	5.6	5.6	5.6	5.6	5.6	5.6
	Weighted dose	21	21	17	17	9.5	3.9	4.2	4.2	4.2	4.2
Thyroid scan	¹³¹ I-sodium iodide	666	666	666	1008	1332	1332	1332	1332	1332	1332
	¹²³ I-sodium iodide	-	-	12	12	24	36	36	47	47	47
	^{99m} Tc-pertechnetate	-	1.6	1.6	1.6	4.1	4.1	4.1	4.9	4.9	4.9
	Weighted dose	666	586	354	225	261	198	148	145	133	135
Thyroid uptake	¹³¹ I-sodium iodide	67	67	67	67	67	67	67	67	94	94
	¹²³ I-sodium iodide	-	-	-	24	24	24	24	24	24	24
	^{99m} Tc-pertechnetate	-	0.41	0.41	0.41	0.41	0.41	0.41	-	-	-
	Weighted dose	67	61	62	54	50	50	49	47	57	55
Tumor localization	¹³¹ I-HSA	78	78	78	78	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	6.9	6.9	6.9	6.9	9.2	9.2	11.47	11.47
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	17	17	17	17

Decade and absorbed dose to thyroid (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	^{111}In -capromab pendetide	-	-	-	-	-	-	-	12	12	12	
	^{18}F -FDG	-	-	-	-	-	5.6	5.6	5.6	5.6	5.6	
Weighted dose		78	78	57	12	6.9	6.8	8.7	8.1	8.4	6.9	

^a Procedure not performed.

^b Dose calculations for a $^{99\text{m}}\text{Tc}$ -DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **urinary bladder wall** in 1960–2010 from nuclear medicine examinations.

Table 12

Decade and absorbed dose to urinary bladder wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	¹³¹ I-RIHSA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	¹²⁵ I-HSA	-	0.06	0.06	0.06	0.06	0.06	0.06	-	-	-
	⁵¹ Cr-RBC	0.03	0.03	0.06	0.08	0.11	0.11	0.11	0.11	0.11	0.11
	Weighted dose	0.01	0.01	0.03	0.05	0.06	0.05	0.06	0.05	0.04	0.02
Bone marrow scan	¹⁹⁸ Au-colloid	2.5	2.5	2.5	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.24	0.49	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	^{99m} Tc-albumin colloid	-	-	-	-	0.51	0.51	0.51	-	-	-
	Weighted dose	2.5	1.7	0.79	0.61	0.61	0.60	0.60	0.61	0.61	0.61
Bone scan	⁸⁵ Sr-chloride	2.4	2.4	2.4	-	-	-	-	-	-	-
	⁸⁵ Sr-nitrate	-	2.4	2.4	-	-	-	-	-	-	-
	Na ¹⁸ F	-	12	16	-	-	-	-	-	-	-
	^{99m} Tc-polyphosphate	-	27	27	36	36	-	-	-	-	-
	^{99m} Tc-MDP	-	-	27	36	36	36	36	44	44	44
	Weighted dose	2.4	8.5	18	36	36	36	36	44	44	44
Brain blood flow	¹³¹ I-RIHSA	7.3	7.3	7.3	7.3	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	8.3	10	13	13	13	13	-	-	-
	^{99m} Tc-DTPA	-	46	46	46	46	46	46	46	46	46
	^{99m} Tc-HMPAO	-	-	-	-	-	17	17	17	17	17
	^{99m} Tc-ECD	-	-	-	-	-	-	6.4	6.4	6.4	6.4
	¹¹¹ In-DTPA	-	-	-	-	4.6	4.6	4.6	4.6	4.6	4.6
Weighted dose	7.3	11	17	31	34	33	29	27	26	26	

Decade and absorbed dose to urinary bladder wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Brain blood flow w. blocking agent	¹³¹ I-RIHSA	7.3	7.3	7.3	7.3	-	-	-	-	-	-
	^{99m} Tc-pertechnetate w. blocking agent	-	14	17	22	22	22	22	-	-	-
	^{99m} Tc-DTPA	-	46	46	46	46	46	46	46	46	46
	^{99m} Tc-HMPAO	-	-	-	-	-	17	17	17	17	17
	^{99m} Tc-ECD	-	-	-	-	-	-	6.4	6.4	6.4	6.4
	¹¹¹ In-DTPA	-	-	-	-	4.6	4.6	4.6	4.6	4.6	4.6
Weighted dose		7.3	13	22	35	36	35	29	27	26	26
Brain scan	¹⁹⁷ Hg-chlormerodrin	3.6	3.6	3.6	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	9.6	9.6	-	-	-	-	-	-	-	-
	^{99m} Tc-pertechnetate	-	14	17	22	22	22	22	-	-	-
	^{99m} Tc-DTPA	-	-	46	46	46	46	46	46	46	46
	^{99m} Tc-glucuheptonate	-	-	-	41	41	41	-	-	-	-
	^{99m} Tc-HMPAO	-	-	-	-	-	17	17	17	17	17
	^{99m} Tc-ECD	-	-	-	-	-	-	37	37	37	37
	²⁰¹ Tl-chloride	-	-	-	-	-	4.3	4.3	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	72	72	72	72	72
	Weighted dose		8.5	11	19	33	38	36	35	37	43
Cardiac procedures	²⁰¹ Tl-chloride	-	-	4.3	4.3	4.3	4.3	4.3	4.3	5.8	5.8
	^{99m} Tc-sestamibi (1 day)	-	-	-	-	-	11	11	11	11	11
	^{99m} Tc-sestamibi (2 day)	-	-	-	-	-	-	15	15	15	15
	^{99m} Tc-tetrofosmin	-	-	-	-	-	-	16	16	16	16
	^{99m} Tc-RBC	-	-	6.3	6.3	6.3	6.3	6.3	7.1	7.9	7.9
	^{99m} Tc-pyrophosphate	-	27	27	27	27	27	27	-	-	-
	^{99m} Tc-pertechnetate	-	-	6.7	-	-	-	-	-	-	-
	^{99m} Tc-HSA	-	-	-	3.0	-	-	-	-	-	-
	¹⁸ F-FDG	-	-	-	-	-	-	-	48	48	48

Decade and absorbed dose to urinary bladder wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	⁸² Rb-chloride	-	-	-	-	-	-	-	-	-	0.31
	Weighted dose	<i>a</i>	27	13	7.1	7.6	7.7	8.6	9.2	11	11
	^{99m} Tc-RBC	-	6.3	6.3	6.3	6.3	6.3	6.3	7.1	7.9	7.9
	^{99m} Tc-pertechnetate	-	-	3.3	3.3	3.3	3.3	6.7	6.7	6.7	6.7
	Weighted dose	<i>a</i>	6.3	6.2	5.8	6.1	6.0	6.3	7.1	7.8	7.8
Hepatobiliary scan	¹³¹ I-Rose Bengal	-	1.4	1.4	1.4	1.4	-	-	-	-	-
	^{99m} Tc-HIDA	-	-	-	3.7	3.7	3.7	3.7	3.7	3.7	3.7
	^{99m} Tc-DISIDA	-	-	-	-	-	3.7	3.7	3.7	3.7	3.7
	^{99m} Tc-mebrofenin	-	-	-	3.7	3.7	3.7	3.7	-	-	-
	Weighted dose	<i>a</i>	1.4	1.4	2.0	3.3	3.7	3.7	3.7	3.7	3.7
Iron metabolism	⁵⁹ Fe-citrate	0.34	0.34	0.34	0.34	0.34	0.34	0.34	-	-	-
	Weighted dose	0.34	0.34	0.34	0.34	0.34	0.34	0.34	<i>a</i>	<i>a</i>	<i>a</i>
Kidney scan	¹³¹ I-hippurate	-	8.5	8.5	8.5	8.5	8.5	8.5	-	-	-
	¹⁹⁷ Hg-chlormerodrin	0.52	0.52	0.78	-	-	-	-	-	-	-
	²⁰³ Hg-chlormerodrin	1.4	1.4	-	-	-	-	-	-	-	-
	^{99m} Tc-DTPA	-	-	23	23	23	23	23	23	23	23
	^{99m} Tc-DMSA	-	-	-	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	^{99m} Tc-glucuheptonate	-	-	31	31	31	31	26	21	21	-
	^{99m} Tc-MAG3	-	-	-	-	-	-	41	41	41	41
	Weighted dose	0.99	3.9	10	19	18	20	32	32	38	39
Liver scan	¹⁹⁸ Au-colloid	0.33	0.33	0.33	-	-	-	-	-	-	-
	¹³¹ I-Rose Bengal	0.06	1.4	-	-	-	-	-	-	-	-
	^{99m} Tc-SC	-	0.08	0.12	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	^{99m} Tc-IDA	-	-	-	-	3.7	3.7	3.7	3.7	3.7	3.7

Decade and absorbed dose to urinary bladder wall (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Lung perfusion	Weighted dose	0.32	0.44	0.14	0.20	0.45	0.83	0.76	0.80	0.94	0.97
	¹³¹ I-MAA	5.8	5.8	5.8	5.8	-	-	-	-	-	-
	^{99m} Tc-MAA	-	0.97	0.97	1.3	1.6	1.6	1.6	1.6	1.6	1.6
	^{99m} Tc-HAM	-	-	1.9	1.9	1.9	3.1	-	-	-	-
Lung ventilation	Weighted dose	5.8	5.4	2.8	1.6	1.7	1.7	1.6	1.6	1.6	1.6
	¹³³ Xe	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	^{99m} Tc-DTPA aerosol	-	-	-	-	1.3 <i>b</i>	1.3 <i>b</i>	1.3 <i>b</i>	1.3 <i>b</i>	1.3 <i>b</i>	1.3 <i>b</i>
	Weighted dose	<i>a</i>	0.06	0.06	0.06	0.19 <i>b</i>	0.38 <i>b</i>	0.47 <i>b</i>	0.51 <i>b</i>	0.84 <i>b</i>	0.90 <i>b</i>
Pancreas scan	⁷⁵ Se-methionine	15	15	15	15	15	-	-	-	-	-
	^{99m} Tc-SC	-	-	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	¹⁸ F-FDG	-	-	-	-	72	72	72	72	72	72
	Weighted dose	15	15	12	12	16	51	54	54	54	54
Thyroid scan	¹³¹ I-sodium iodide	0.85	0.85	0.85	1.3	1.7	1.7	1.7	1.7	1.7	1.7
	¹²³ I-sodium iodide	-	-	0.26	0.26	0.51	0.77	0.77	1.0	1.0	1.0
	^{99m} Tc-pertechnetate	-	1.3	1.3	1.3	3.3	3.3	3.3	4.0	4.0	4.0
	Weighted dose	0.85	0.91	1.0	1.2	2.4	2.4	2.2	2.3	2.3	2.1
Thyroid uptake	¹³¹ I-sodium iodide	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.12	0.12
	¹²³ I-sodium iodide	-	-	-	0.51	0.51	0.51	0.51	0.51	0.51	0.51
	^{99m} Tc-pertechnetate	-	0.33	0.33	0.33	0.33	0.33	0.33	-	-	-
	Weighted dose	0.09	0.10	0.10	0.17	0.21	0.21	0.25	0.28	0.32	0.33
Tumor localization	¹³¹ I-HSA	54	54	54	54	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	9.0	9.0	9.0	9.0	12	12	15	15
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	44	44	44	44
	Weighted dose	0.09	0.10	0.10	0.17	0.21	0.21	0.25	0.28	0.32	0.33

Decade and absorbed dose to urinary bladder wall (mGy)												
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010	
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	14	14	14	
	¹⁸ F-FDG	-	-	-	-	-	72	72	72	72	72	
Weighted dose		54	54	41	12	9.0	11	21	39	54	68	

^a Procedure not performed.

^b Dose calculations for a ^{99m}Tc-DTPA aerosol administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)

Table 13

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the brain in 1960–2010 from nuclear medicine examinations.

Decade and absorbed dose to brain (mGy)											
Type of examination	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	^{99m} Tc-RBC	-	2.7	2.7	2.7	2.7	2.7	2.7	3.0	3.3	3.3
	^{99m} Tc-pertechnetate	-	-	0.37	0.37	0.37	0.37	0.74	0.74	0.74	0.74
	Weighted dose	<i>a</i>	2.7	2.6	2.3	2.5	2.4	2.6	2.9	3.3	3.3
Pancreas scan	⁷⁵ Se-methionine	13	13	13	13	13	-	-	-	-	-
	^{99m} Tc-SC	-	-	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
	¹⁸ F-FDG	-	-	-	-	21	21	21	21	21	21
Weighted dose		13	13	10	10	8.1	15	16	16	16	16

^aProcedure not performed.

Table 14

Estimates of the weighted doses and radiopharmaceutical-specific absorbed doses (mGy) to the **esophagus** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to esophagus (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
GI bleeding and Meckel's scan	^{99m}Tc -RBC	-	4.5	4.5	4.5	4.5	4.5	4.5	5.1	5.6	5.6
	^{99m}Tc -pertechnetate	-	-	0.44	0.44	0.44	0.44	0.89	0.89	0.89	0.89
	Weighted dose	<i>a</i>	4.5	4.4	3.8	4.2	4.1	4.4	5.0	5.5	5.5
Pancreas scan	^{75}Se -methionine	15	15	15	15	15	-	-	-	-	-
	^{99m}Tc -SC	-	-	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
	^{18}F -FDG	-	-	-	-	6.7	6.7	6.7	6.7	6.7	6.7
Weighted dose		15	15	12	12	7.3	4.8	5.1	5.1	5.1	5.1

^a Procedure not performed.

Table 15

Estimates of the weighted doses and radiopharmaceutical's absorbed doses (mGy) to **heart wall** in 1960–2010 from nuclear medicine examinations.

Type of examination	Radiopharmaceutical	Decade and absorbed dose to heart wall (mGy)									
		1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
Blood volume	^{131}I -R-HSA	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	^{125}I -HSA	-	0.19	0.19	0.19	0.19	0.19	0.19	-	-	-
	^{51}Cr -RBC	0.19	0.19	0.38	0.57	0.75	0.75	0.75	0.75	0.75	0.75
	Weighted dose	0.07	0.08	0.18	0.35	0.38	0.33	0.37	0.31	0.26	0.13
Cardiac procedures	^{201}Tl -chloride	-	-	21	21	21	21	21	21	28	28
	$^{99\text{m}}\text{Tc}$ -sestamibi (1 day)	-	-	-	-	-	8.0	8.0	8.0	8.0	8.0
	$^{99\text{m}}\text{Tc}$ -sestamibi (2 day)	-	-	-	-	-	-	11	11	11	11
	$^{99\text{m}}\text{Tc}$ -tetrofosmin	-	-	-	-	-	-	5.8	5.8	5.8	5.8
	$^{99\text{m}}\text{Tc}$ -RBC	-	-	-	-	-	-	25	25	25	25
	$^{99\text{m}}\text{Tc}$ -pyrophosphate	-	-	17	17	17	17	17	19	21	21
	$^{99\text{m}}\text{Tc}$ -pertechnetate	-	0.67	0.67	0.67	0.67	0.67	0.67	-	-	-
	$^{99\text{m}}\text{Tc}$ -HSA	-	-	1.1	-	-	-	-	-	-	-
	^{18}F -FDG	-	-	-	15	-	-	-	-	-	-
	^{82}Rb -chloride	-	-	-	-	-	-	25	25	25	25
GI bleeding and Meckel's scan	Weighted dose	<i>a</i>	0.67	6.5	18	18	17	15	13	13	11
	$^{99\text{m}}\text{Tc}$ -RBC	-	17	17	17	17	17	17	19	21	21
	$^{99\text{m}}\text{Tc}$ -pertechnetate	-	-	0.57	0.57	0.57	0.57	1.1	1.1	1.1	1.1
	Weighted dose	<i>a</i>	17	16	14	16	15	16	19	21	21
Iron metabolism	^{59}Fe -citrate	1.2	1.2	1.2	1.2	1.2	1.2	1.2	-	-	-
	Weighted dose	1.2	1.2	1.2	1.2	1.2	1.2	1.2	<i>a</i>	<i>a</i>	<i>a</i>
Pancreas scan	^{75}Se -methionine	17	17	17	17	17	-	-	-	-	-
	$^{99\text{m}}\text{Tc}$ -SC	-	-	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Type of examination	Decade and absorbed dose to heart wall (mGy)										
	Radiopharmaceutical	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2010
	¹⁸ F-FDG	-	-	-	-	37	37	37	37	37	37
	Weighted dose	17	17	14	14	13	26	28	28	28	28
Tumor localization											
	¹³¹ I-HSA	211	211	211	211	-	-	-	-	-	-
	⁶⁷ Ga-citrate	-	-	7.7	7.7	7.7	7.7	10	10	13	13
	¹¹¹ In-pentetreotide	-	-	-	-	-	-	5.6	5.6	5.6	5.6
	¹¹¹ In-capromab pendetide	-	-	-	-	-	-	-	30	30	30
	¹⁸ F-FDG	-	-	-	-	-	37	37	37	37	37
	Weighted dose	211	211	152	22	7.7	8.5	14	22	28	33

^aProcedure not performed.

^bDose calculations for an administered activity into the patient's lungs of 27.75 MBq (1300 MBq in the nebulizer)