



@mmahesh1

NCRP 184:

Medical Radiation Exposure of Patients in the United States

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AAPM Virtual Meeting in the Time of COVID-1

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Disclosures

- **Royalties**
 - Lippincott Williams and Wilkins (book)
- **Council Member**
 - National Council on Radiation Protection and Measurements (NCRP)
- **Travel Funding**
 - American College of Radiology (ACR) (Board Member)
 - American Association of Physicists in Medicine (AAPM) (Board Member)



Session on NCRP 184

- Dr M. Mahesh – **Moderator & Speaker**
 - Overview with focus on CT and Nuclear Medicine
- Dr Donald P Frush – Pediatric Imaging
- Dr Donald Miller – Interventional Fluoroscopy

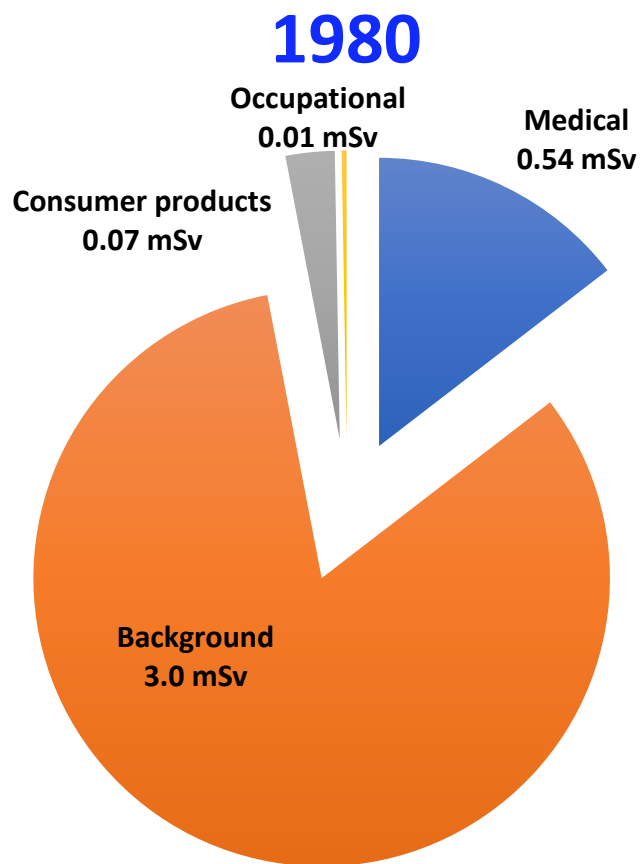


Purpose

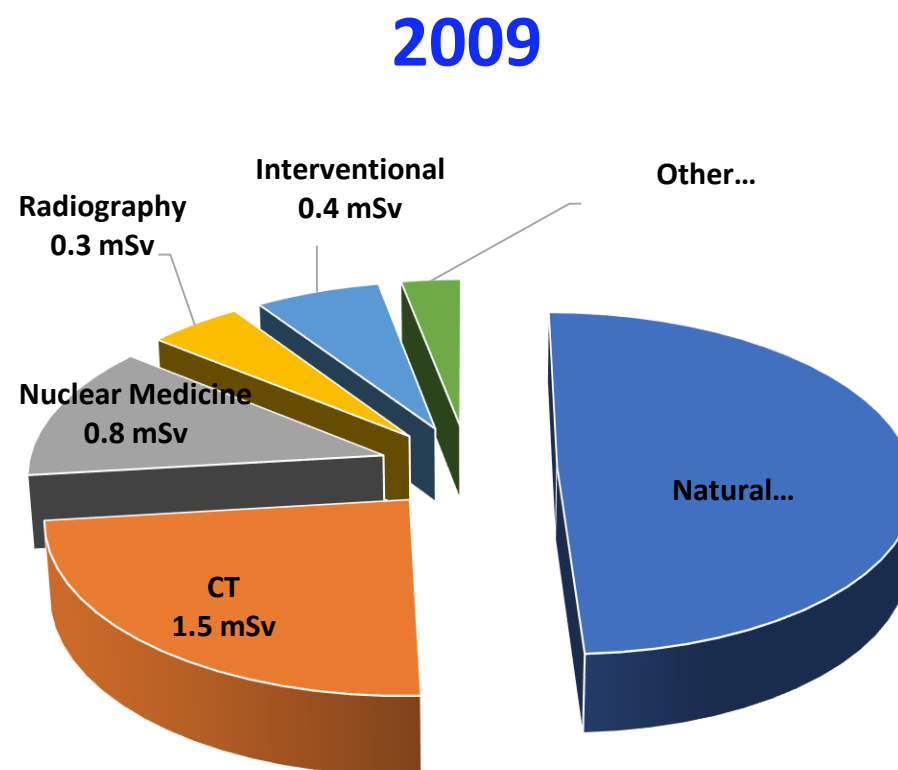
- Prepare report to evaluate changes in medical radiation exposures for US population since 2006 (NCRP 160)
- NCRP 160
 - Published officially in 2009
 - Data from 2006
- This report (NCRP 184)
 - Published officially in November 2019
 - Data from 2016



Past: Radiation Exposures to US population



Medical 0.54 mSv per capita
Total 3.6 mSv per capita



Medical 3.0 mSv per capita
Total 6.2 mSv per capita

NCRP PAC 4-9 Committee Members

- **Chair** **F. Mettler** **Univ of New Mexico** **(Diagnostic Radiology)**
- **Co-Chair** **M. Mahesh** **Johns Hopkins Univ.** **(Medical Physics)**

- **H. Royal** **Wash Univ. St. Louis,** **(Nuclear Medicine)**
- **C. Chambers** **Penn. State** **(Interventional cardiology)**
- **D. Miller** **U.S. FDA CDRH** **(Interventional radiology)**
- **D. Frush** **Duke Univ.** **(Pediatric Radiology)**
- **M. Milano** **Univ of Rochester** **(Radiation Oncology)**
- **D. Spelic** **U.S. FDA** **(NEXT and Dental)**
- **M B. Chatfield** **Exec. VP, Am Coll Radiol.** **(Medicare & data sources)**
- **J. Elee** **State of Louisiana** **(CRCPD + State data)**

- **Advisors: A. Ansari, W. Bolch, G. Guebert, R. Sherrier, J. Smith**
- **R. Vetter, L. Atwell, SciMetrika (literature related) and NCRP staff**



NCRP Report 184

U.S. population data are reported in four metrics

- Number and type of diagnostic and interventional medical radiation procedures
- Procedures: **Exams vs Scans**
 - Scans w multiple exposures (dual-phase studies)
 - 1 exam but 2 scans
- Effective dose (E) per procedure
- Collective Effective Dose (S) per procedure
- U.S. Annual Average Individual Effective Dose (E_{US})*

*allows comparison of the magnitude of medical radiation exposure to that from various non-medical sources

NCRP REPORT No. 184

MEDICAL RADIATION
EXPOSURE OF PATIENTS
IN THE UNITED STATES



National Council on Radiation Protection and Measurements



NCRP Medical Exposure Reports

NCRP REPORT No. 100

EXPOSURE OF THE
U.S. POPULATION
FROM DIAGNOSTIC
MEDICAL RADIATION

Start 1972
Finished 1988
Published 1989

NCRP

National Council on Radiation Protection and Measurements

17 years

NCRP REPORT No. 160

IONIZING RADIATION
EXPOSURE OF THE
POPULATION OF THE
UNITED STATES

Start 2006
Finished 2008
Published 2009

NCRP 1929
2009

3.5 years

NCRP REPORT No. 184

MEDICAL RADIATION
EXPOSURE OF PATIENTS
IN THE UNITED STATES



Start Nov 2016
Finished early 2019
Published Nov 2019



National Council on Radiation Protection and Measurements

3.0 years



Calculations

- Number of Imaging Procedures (**N**)
- Effective dose (**E**) per procedure (mSv)
- Collective Effective Dose (**S**) (person-Sievert) = **E*N**
- Average Individual Effective dose (**E_{US}**) (mSv)
- **E_{US} = S/US population***

* 323 million in 2016



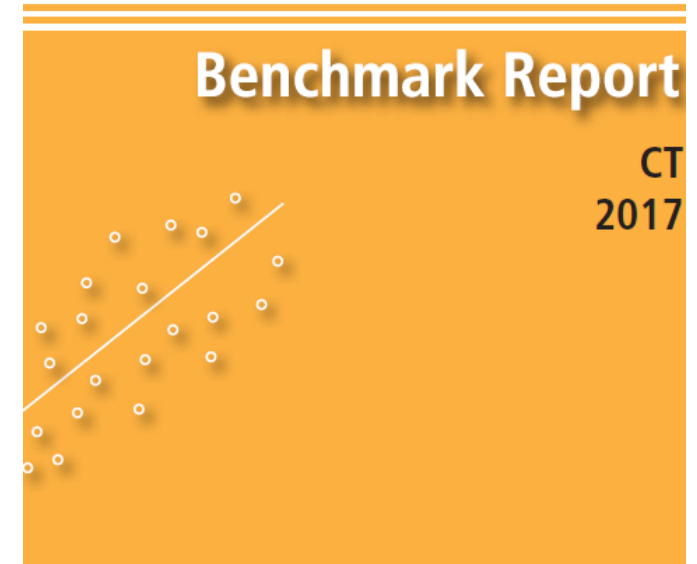
What is **not** included the NCRP 184?

- Discussion of benefits or risks
- Discussion of appropriateness in medicine
- Radiation therapy treatment doses



Major and minor data sources

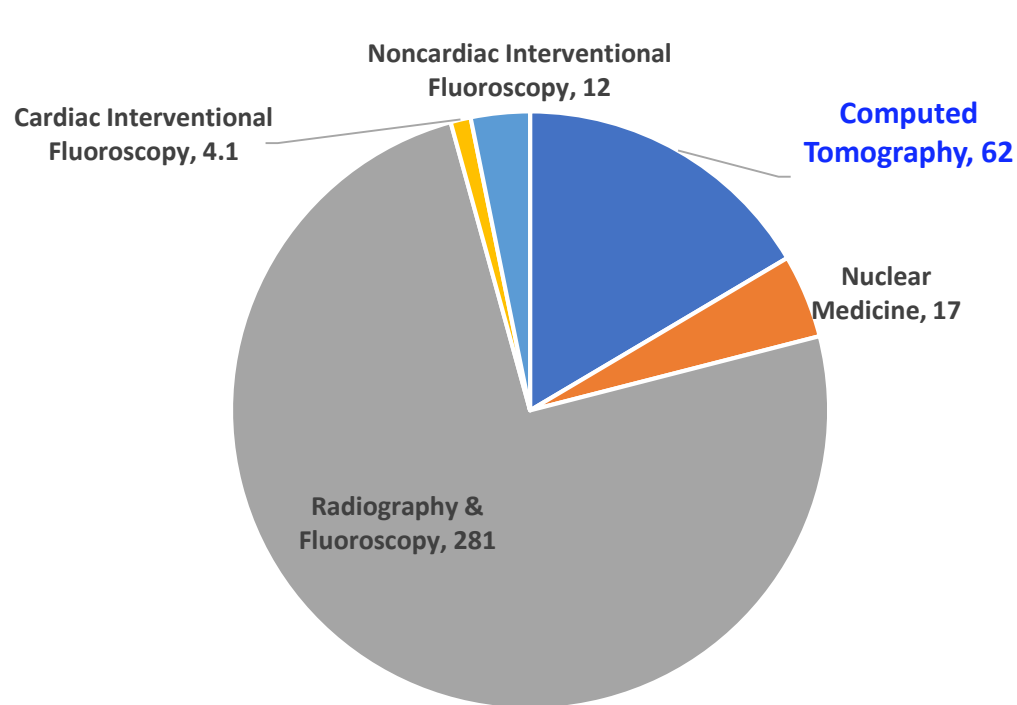
- Commercial (IMV Benchmark)
- Medicare payment data (2003-2016)
- VA Health Care System
- US FDA
- CRCPD
- State radiation programs
- Large hospitals
- American College of Radiology
- Industry sources
- Literature



Results

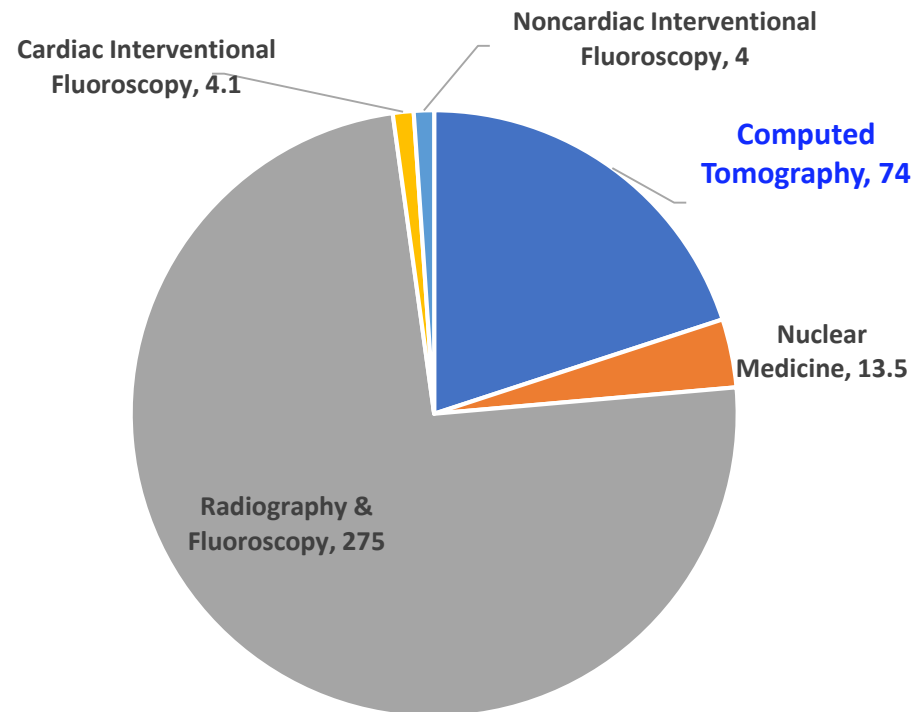


Number of Procedures: 2006 vs 2016



Total: 377 million

2006



Total: 371 million

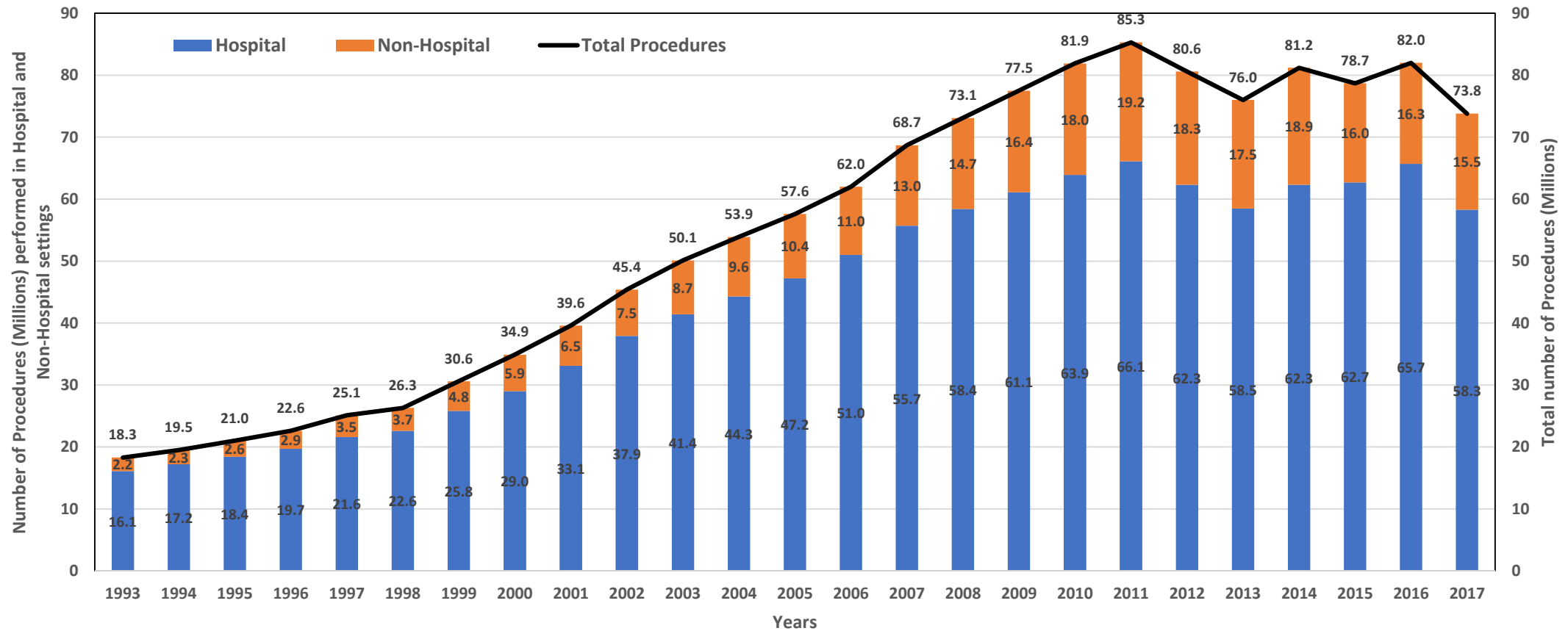
2016



Computed Tomography



Number of CT procedures*

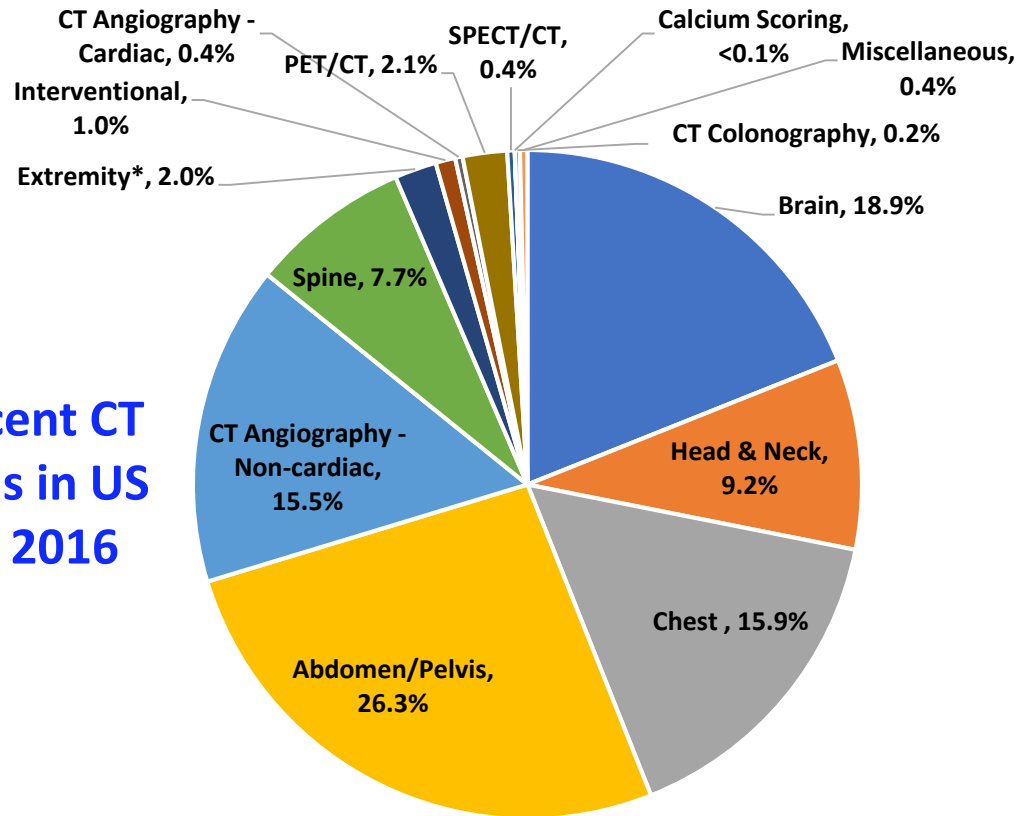


* 2018 IMV Report

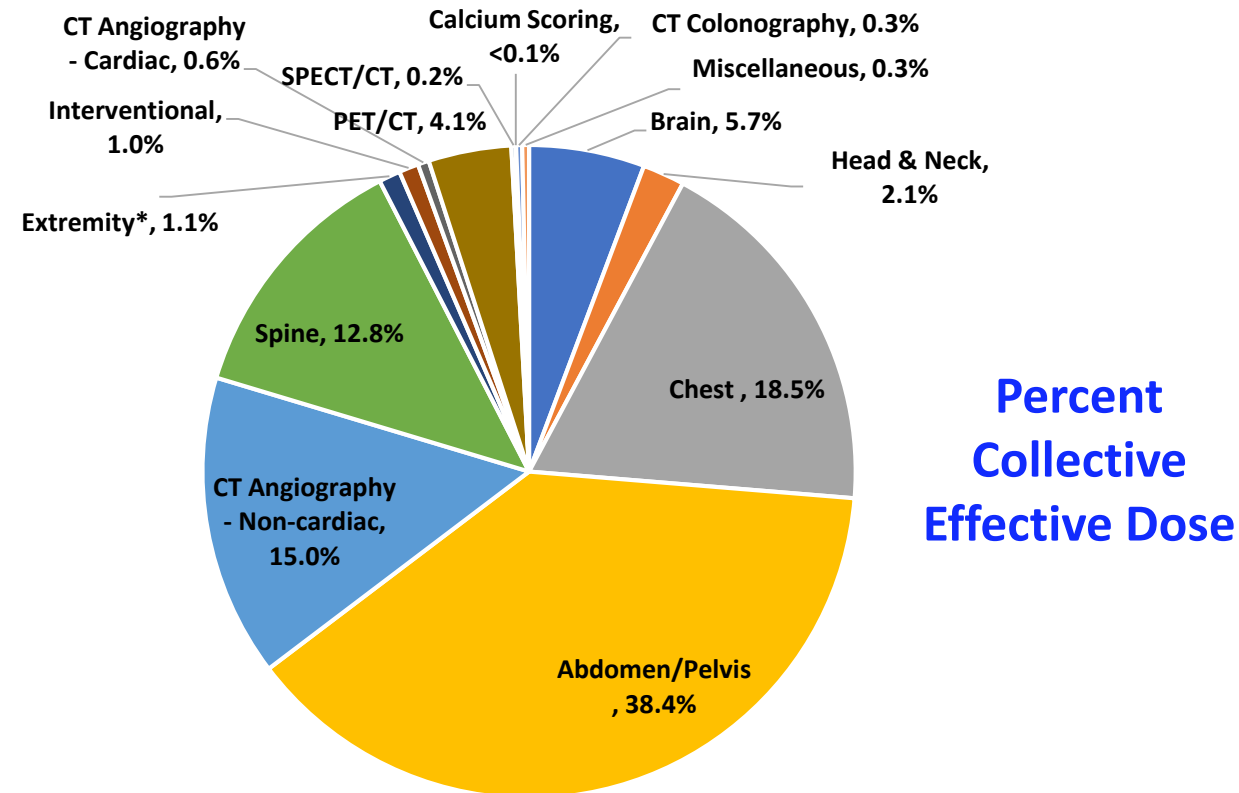
Increased by ~20% over 10 years!

CT: Procedures vs Collective Dose*

Percent CT scans in US for 2016



Collective Effective Dose
Effective Dose per Person



444,000 person-Sv
1.37 mSv

* For 2016 using ICRP 103 w_T s

E_{US} for CT

1.45 mSv (2006) vs 1.37 mSv (2016)

- CT procedures increased: 62 million (2006) to 74 million (2016)
- CT scans increased: 67 million (2006) to 84 million (2016)
- US population increased: 300 million (2006) to 323 million (2016)
- **Average Individual Effective Dose (E_{US}) for CT decreased by ~6% per person in the United States**



Probable causes for decrease in CT dose

- CT procedures higher by ~20 % than in 2006
- US population higher by 23 million than in 2006
- Decrease in effective dose per CT procedure is real!
- All this contributes towards ~6% reduction in individual effective dose

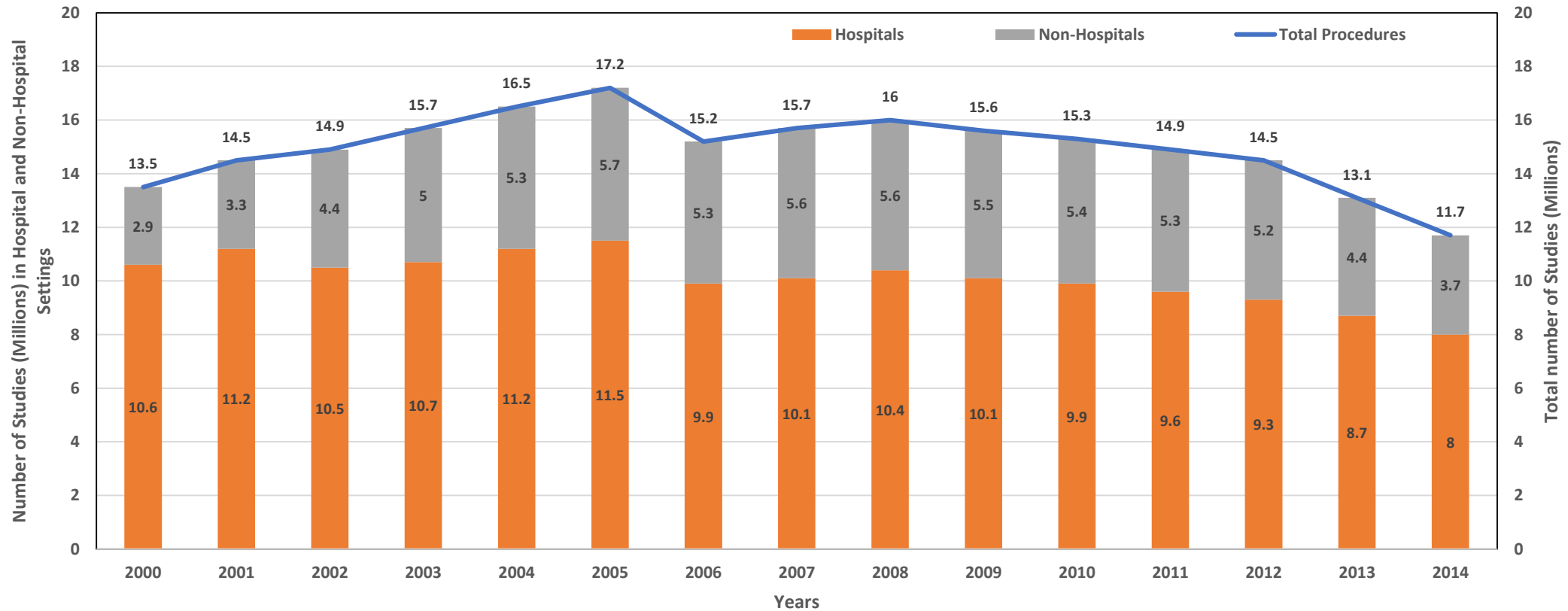
1.46 mSv (2006) vs 1.37 mSv (2016)



Nuclear Medicine



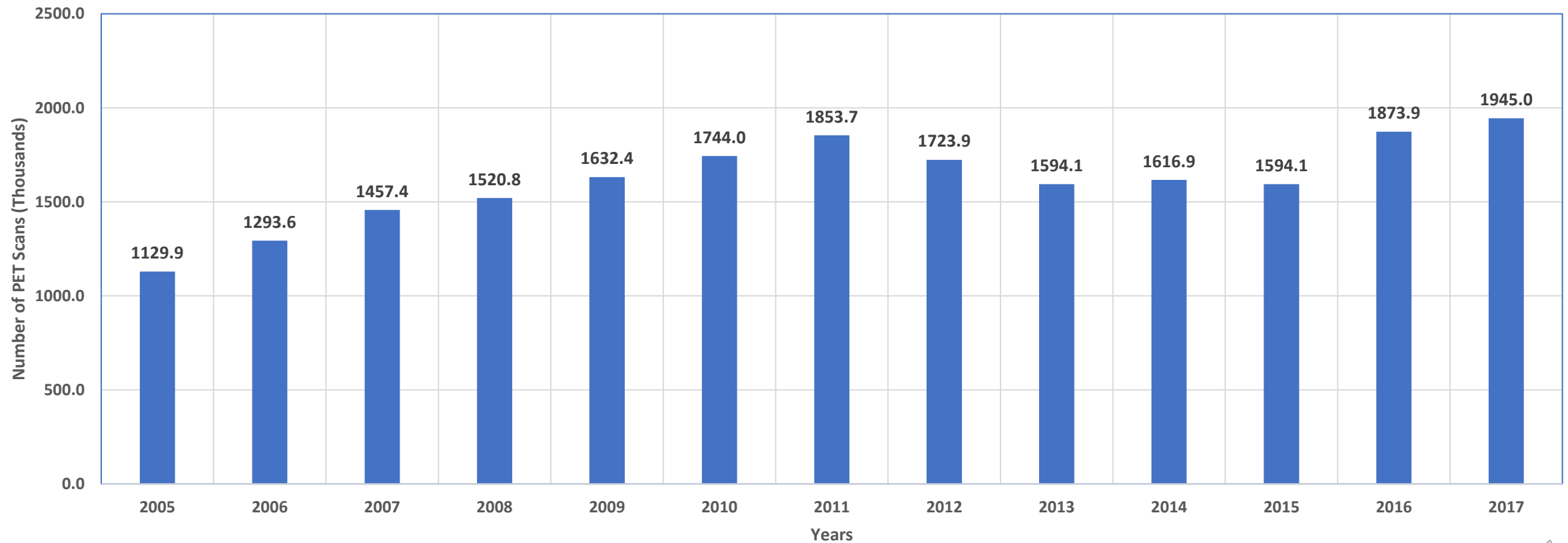
Number of Nuclear Medicine Procedures



* 2015 IMV Report

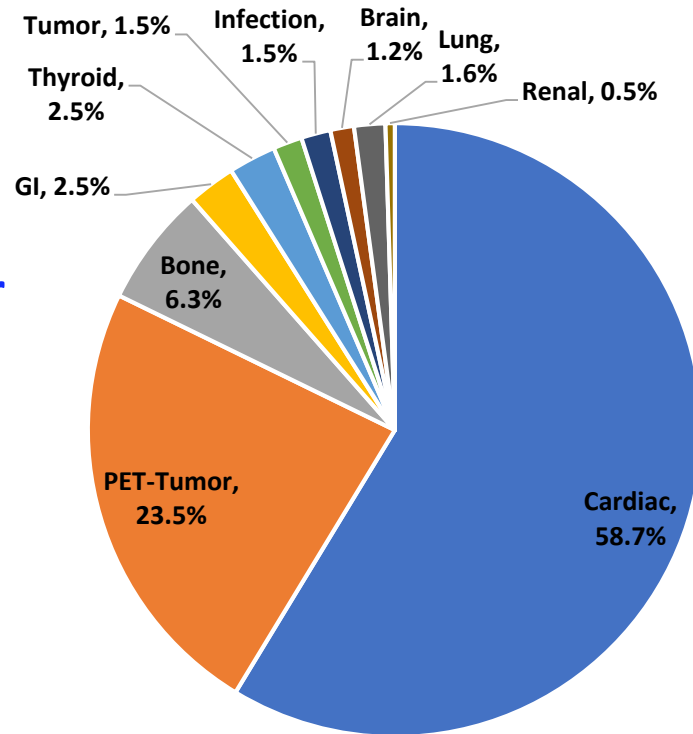
Decreased by ~20% over 10 years!

Trend in PET and PET/CT scans

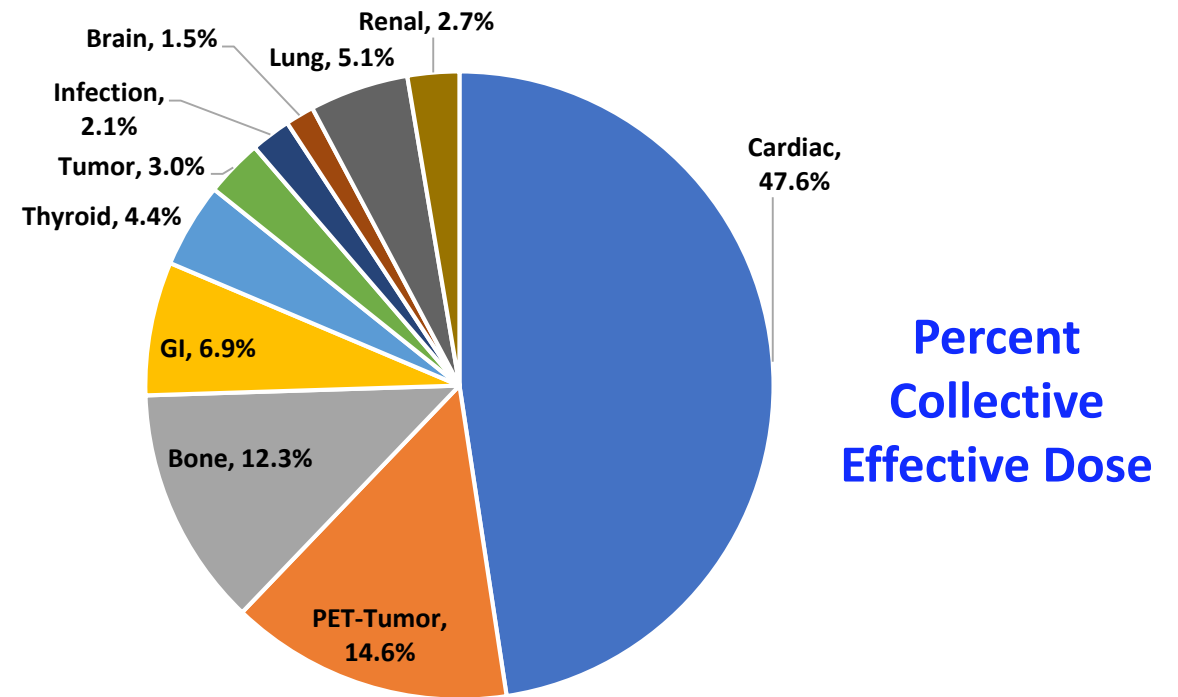


Nuclear Medicine: Procedures vs Collective Dose*

Percent Nuclear
Medicine
Procedures in
US for 2016



Collective Effective Dose
Effective Dose per Person



Percent
Collective
Effective Dose

106,000 person-Sv
0.32 mSv

* For 2016 using ICRP 103 w_T s

E_{US} for Nuclear Medicine

0.73 mSv (2006) vs 0.32 mSv (2016)

- Nuclear Medicine procedures decreased from
~17 million (2006) to 13.5 million (2016)
- However, there was substantial increase in PET/CT scans
- US population increased: 300 million (2006) to 323 million (2016)
- Average Individual Effective Dose (E_{US}) for NM decreased by
~56% per person in the United States



Probable causes for decrease in NM dose

- Decrease in number of procedures: 20% lower than 2006
- Use of radioactivity injected after optimized for weight
- Use of new models to estimate effective dose
- All 3 together may have contributed towards >50% reduction in individual effective dose

0.73 mSv (2006) vs 0.32 mSv (2016)



Impact of Tissue Weighting Factors

ICRP 60 vs ICRP 103

- **Effective dose per person estimated using both ICRP 60 and 103 weighting factors, in order to compare results with NCRP 160**
- **Effective dose per procedure**
 - **Decrease for procedures that includes pelvis region**
 - **Increase for procedures that includes chest region**



Tissue Weighting Factors (w_T)

Organ or Tissue	Weighting factor*	
	ICRP 60	ICRP 103
Breast	0.05	0.12
Red bone marrow, Colon, Lung, Stomach	0.12	0.12
Remainder [†] tissues	0.12	0.12
Gonads	0.20	0.08
Bladder, Liver, Thyroid & Esophagus	0.05	0.04
Skin & Bone surface	0.01	0.01
Brain & Salivary glands		0.01

[†]Accounts additional tissues/organs such as adrenals, kidney, small and large intestine, muscle, pancreas, spleen, thymus and uterus

* ICRP 103, 2007



Effective doses for CT exams

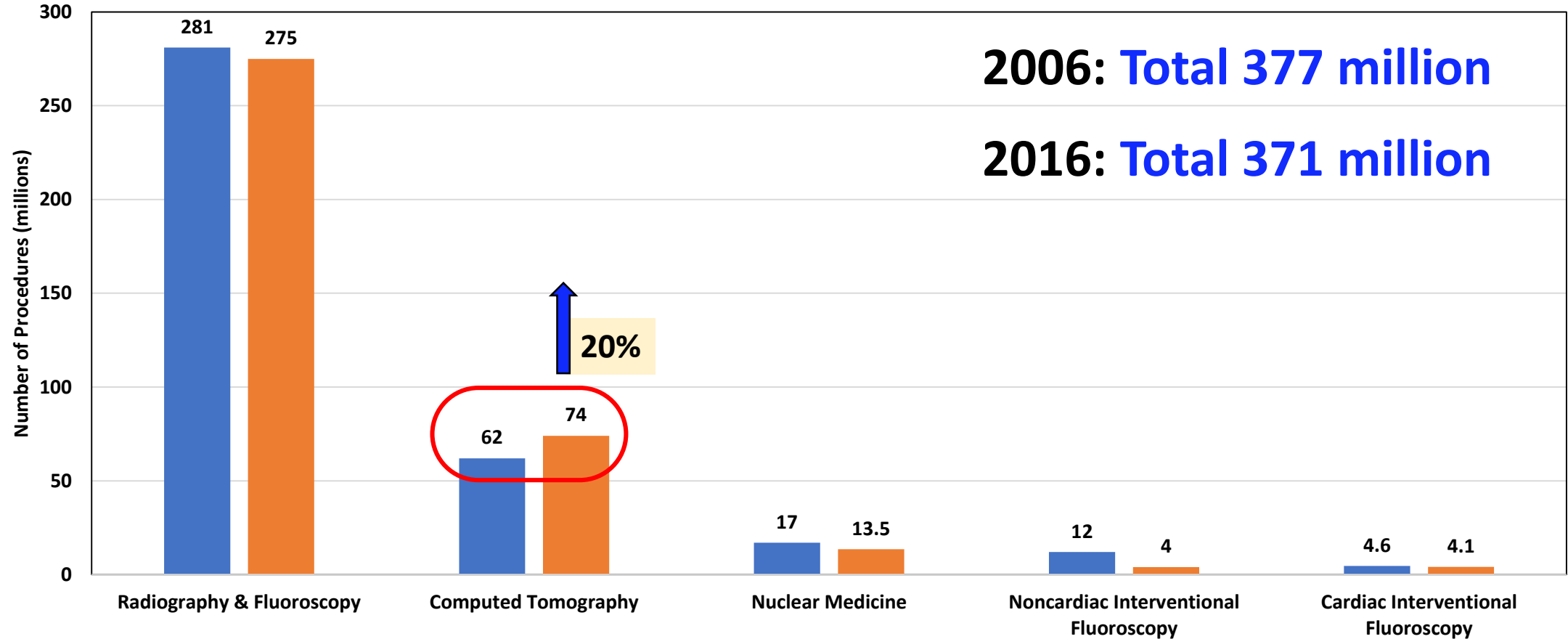
(Impact of ICRP 103)

Type of CT Scan	Eff dose (mSv) ICRP 60	Choice of E_{103}/E_{60}	Eff dose (mSv) ICRP 103
Brain	1.9	0.84	1.6
Head & Neck	1.4	0.87	1.2
Chest CT	5.4	1.14	6.1
Cardiac CT	7.6	1.14	8.7
Abdomen & Pelvis	8.7	0.88	7.7
CT Colonography	7.5	0.88	6.6
Spine	9.2	0.96	8.8
CT Angiography (non-cardiac)	5.4	0.94	5.1
Interventional	5.2	0.96	5.0
PET-CT	10.0	1	10.0

Summary



Number of Procedures: 2006 vs 2016



Estimated Procedures, Collective Effective Doses and Average Individual Effective Dose by modality for 2016*

	Procedures (millions)	%	S (person-Sv)	%	E_{us} (mSv)
Computed Tomography	74	24%	440,000	78%	1.37
Nuclear Medicine	13.5		106,000		0.32
Radiography & Fluoroscopy	275	74	71,000	10	0.22
Cardiac Interventional Fluoroscopy	4.1	1	42,000	6	0.13
Non-cardiac Interventional Fluoroscopy	4.0	1	40,000	6	0.12
Total	371		703,000		2.16

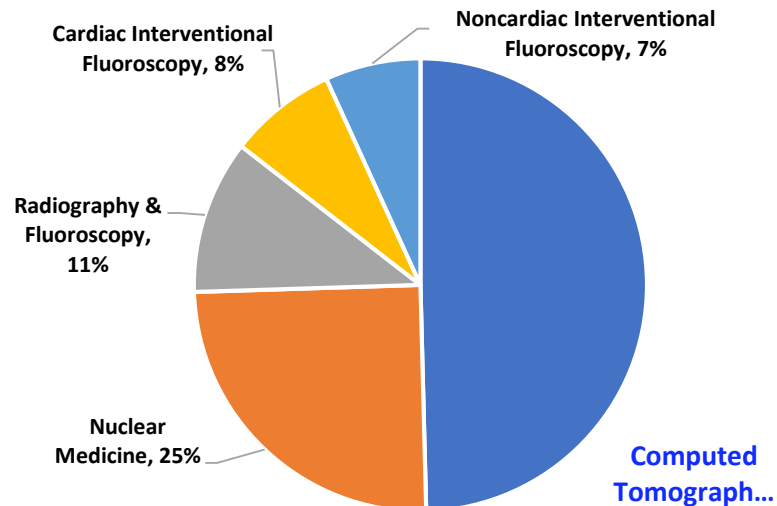
* Based on ICRP 103 tissue-weighting factors

Results

2006_{ICRP60}

885,000 person-Sievert

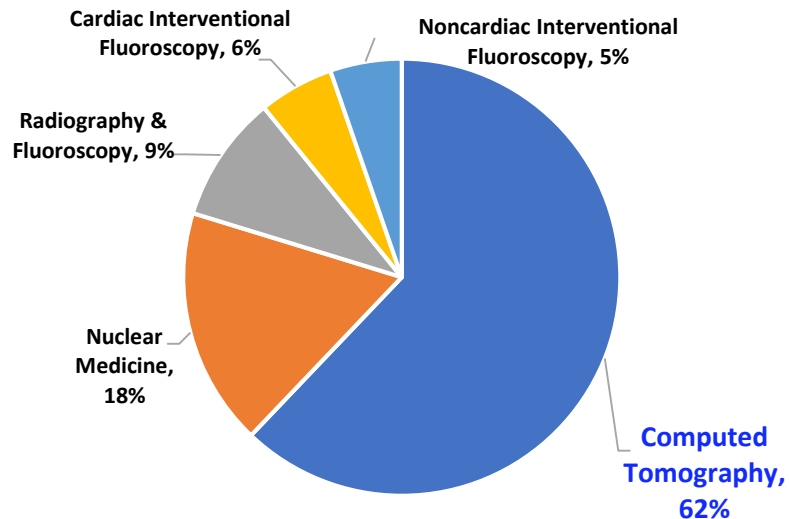
2.92 mSv/person



2016_{ICRP60}

755,000 person-Sievert

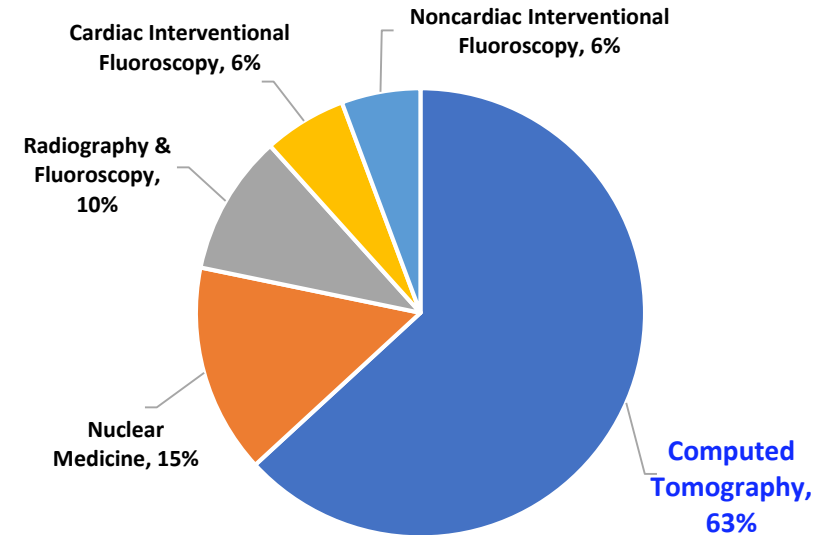
2.33 mSv/person



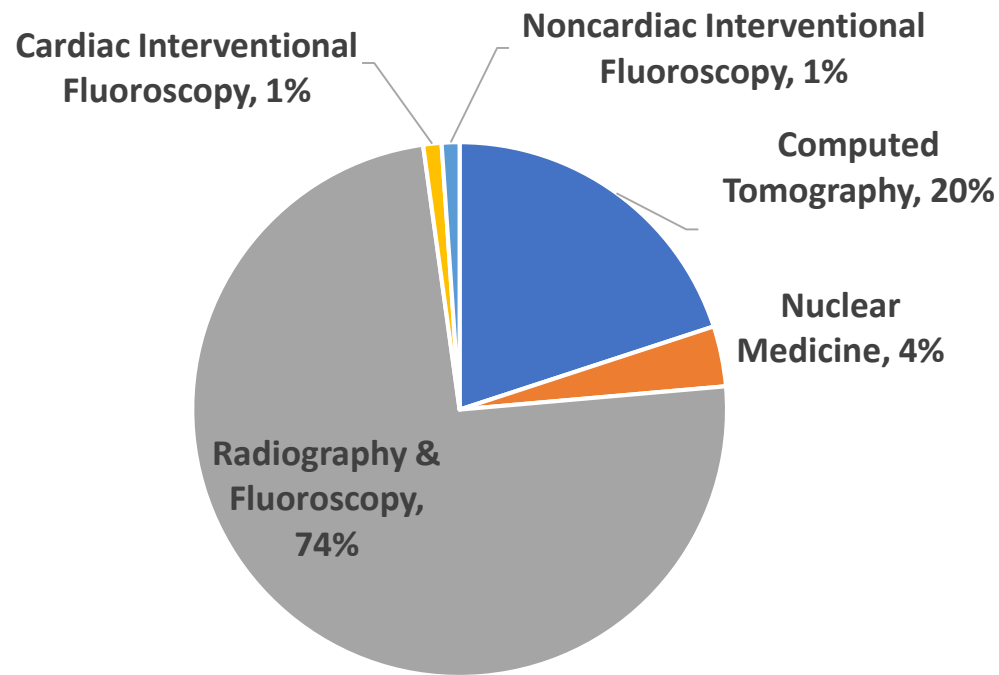
2016_{ICRP103}

717,000 person-Sievert

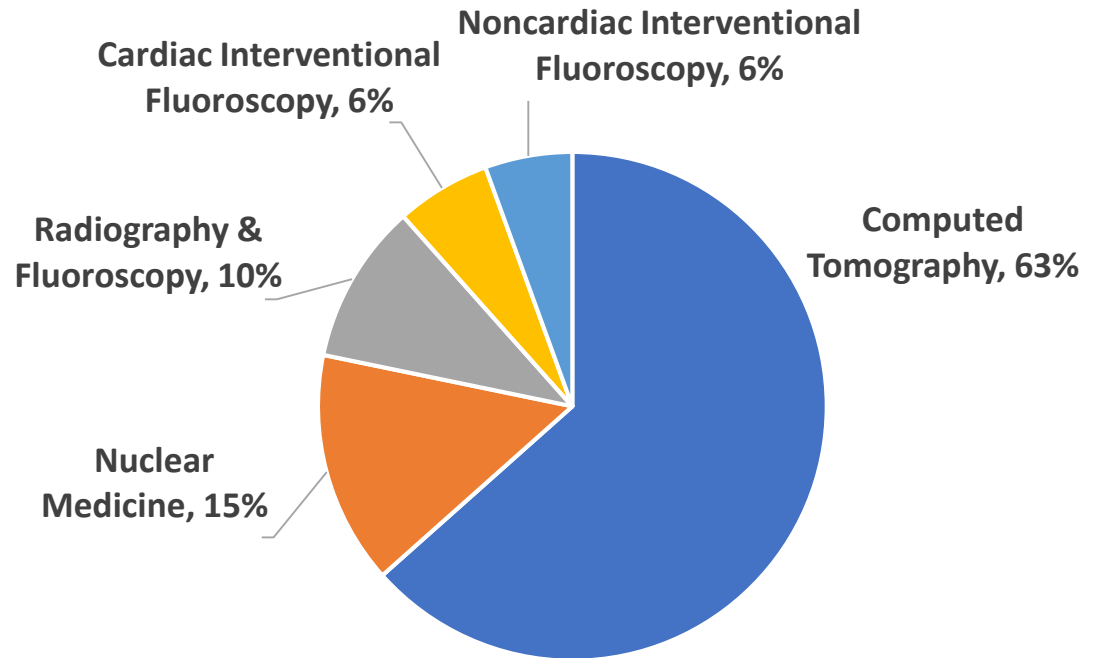
2.16 mSv/person



Percent Procedures vs Average Individual Effective Dose for US during 2016



**% Radiation Imaging Procedures
in US during 2016**



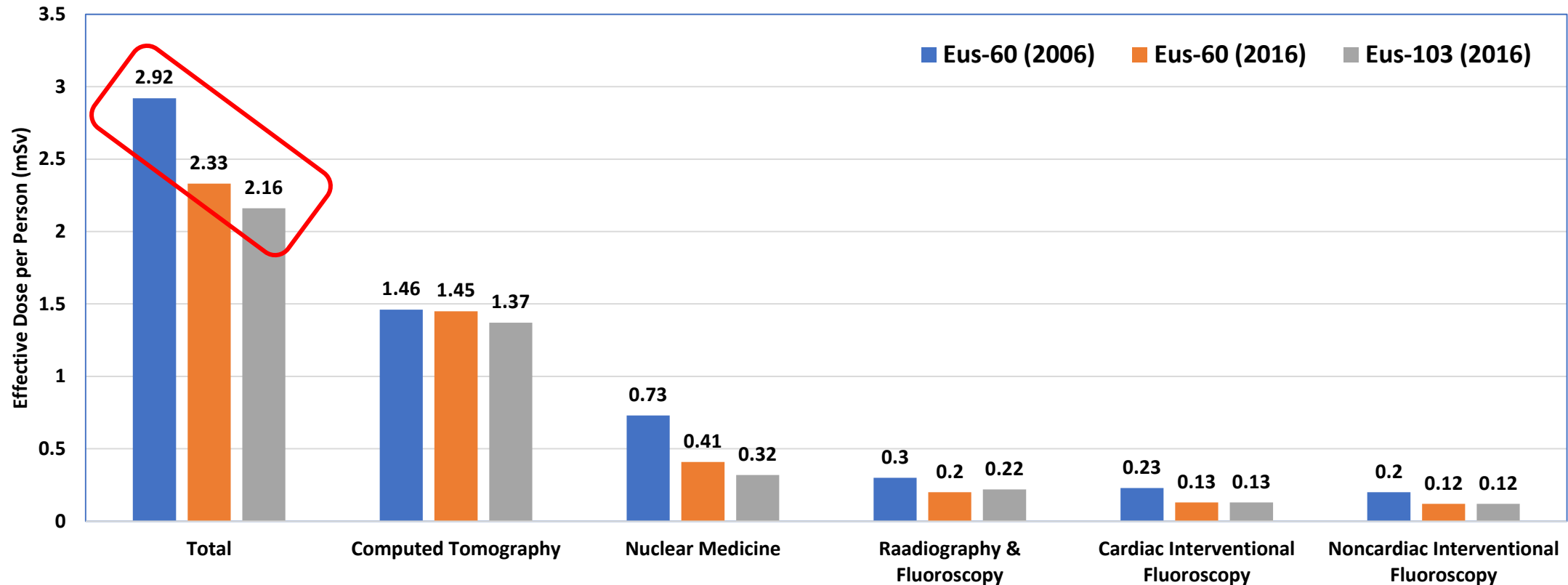
**% Average Effective Dose per
capita for US population in 2016**

*using ICRP 103 tissue weighting factors

*values are not per patient, but per person in the US population

Average effective dose per person for US Population*

(Comparison between 2006 and 2016 computed with ICRP publications 103 and 60 Tissue Weighting Factors)

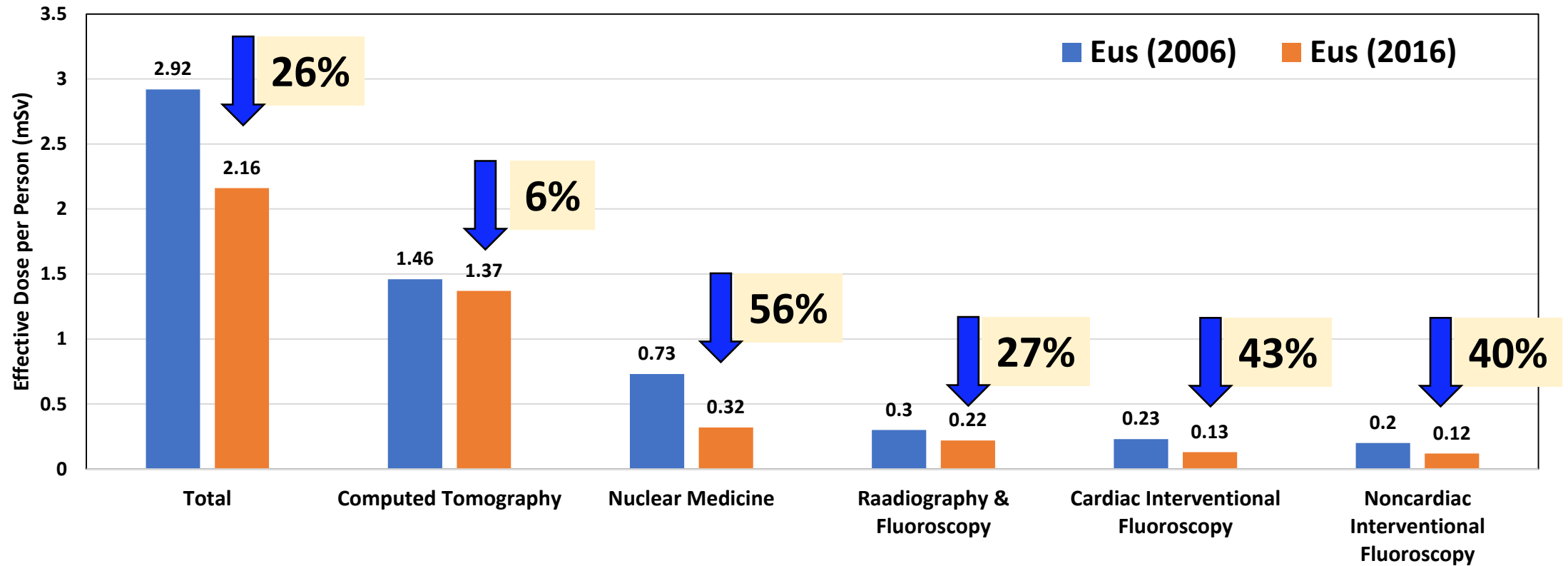


*values are not per patient, but per person in the US population



Average effective dose per person for US Population*

2006 vs 2016



*values are not per patient, but per person in the US population

The Dream Team



Key Messages

Compared to 2006 (NCRP 160), 2016 data (NCRP 184) demonstrates that medical radiation dose to US population

- **Decreased by ~15-20%** across all x-ray imaging modalities
- **Decreased by >50%** for Nuclear Medicine, predominantly due to decrease in procedures
- **Decrease by ~6%** for Computed Tomography, in-spite of 20% increase in CT procedures



Summary

Decrease in Medical Radiation Exposure to Patients in the United States may be due to:

- **Advances in medical imaging technologies**
- **Optimization of imaging protocols and accreditation of modalities**
- **Increase awareness about radiation by Image Gently[®], Image Wisely[®], Choosing Wisely[®] and others**

Medical community can continue to leverage benefits of radiological procedures for patients in the United States while lowering dose



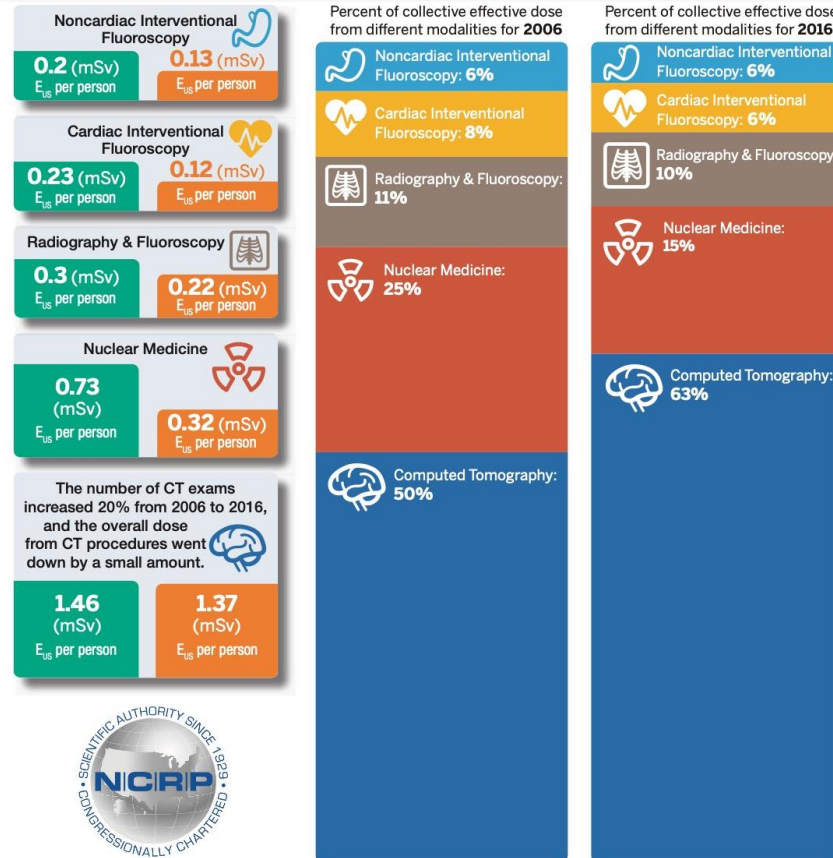
U.S. Medical Radiation Doses Are Decreasing

Annual non-therapeutic medical radiation dose to the U.S. population in 2016 is 15-20% lower than it was in 2006.

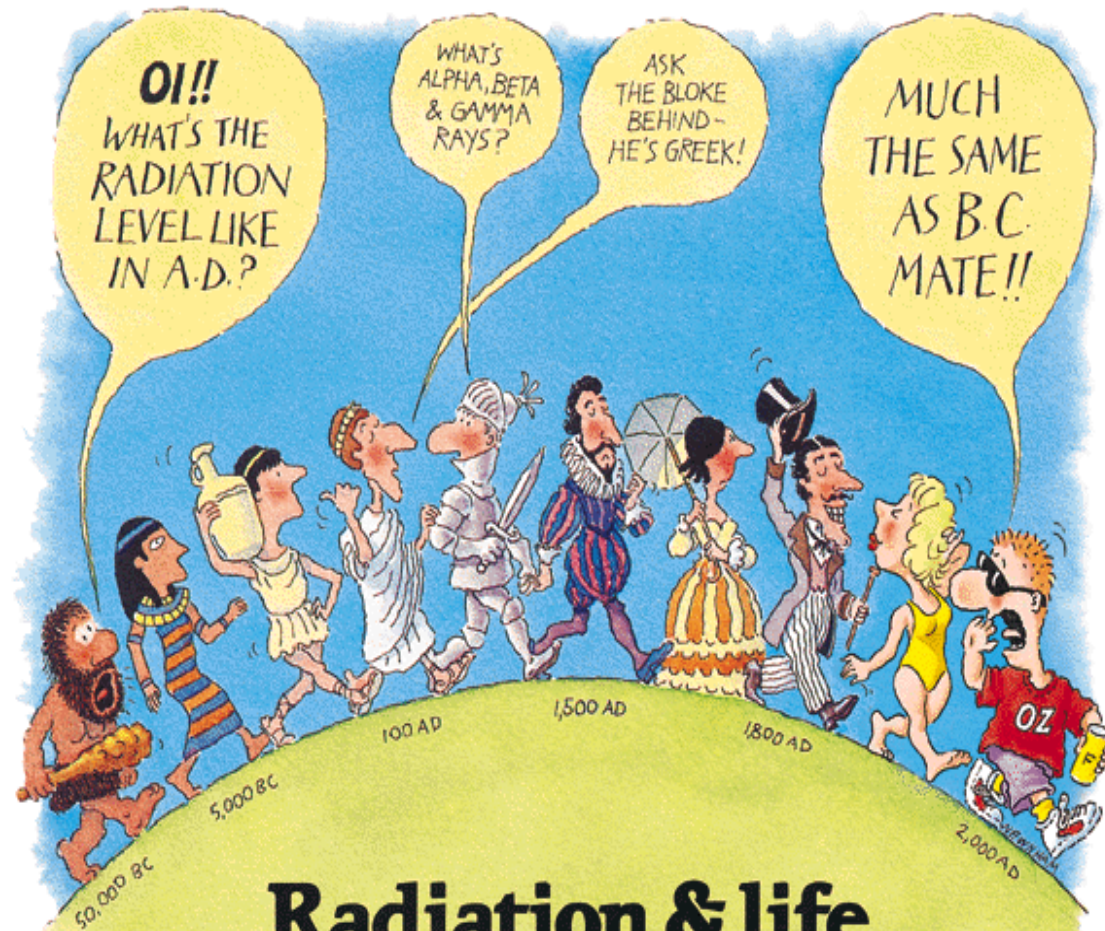
2006
2016

2.92
(mSv)
Estimated Average
Individual Effective Dose
(E_{iso}) per person

2.16
(mSv)
Estimated Average
Individual Effective Dose
(E_{iso}) per person



Note: When current data are compared with NCRP Report 160 utilizing ICRP weighting factors from ICRP Publication 60, the results are the same except for Nuclear Medicine (0.41 mSv), Computed Tomography (1.45 mSv) and total dose (2.33 mSv). For more detail, please see Figure 14.2 in the report.



Radiation & life

"Life on earth has developed with an ever present background of radiation. It is not something new, invented by the wit of man; radiation has always been there."

Eric J Hall, Professor of Radiology, College of Physicians and Surgeons, Columbia University, New York. "Radiation and Life".

