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Pacific Northwest National Laboratory
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Medical Radioisotope Data Survey: 2002 Preliminary Results

ER Siciliano

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Radiation Portal Monitor Project

Medical Radioisotope Data Survey: 2002 Preliminary Results

E.R. Siciliano

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SUMMARY

A limited, but accurate amount of detailed information about the radioactive isotopes used in the U.S. for medical procedures was collected from a local hospital and from a recent report on the U.S. Radiopharmaceutical Markets. These data included the total number of procedures, the specific types of procedures, the specific radioisotopes used in these procedures, and the dosage administered per procedure. The information from these sources was compiled, assessed, pruned, and then merged into a single, comprehensive and consistent set of results presented in this report. A summary of these results is given in Table 2-1, and displayed as distributions in Figures 1a and 1b.

The main findings from this preliminary survey are:

- A total of approximately 14.4 million medical procedures using radioisotopes were performed in the U.S. during 2001.
- Of this total number of procedures during 2001, approximately 14.2 million were diagnostic procedures and 0.2 million were therapeutic procedures.
- Although there were over 45 different commercially-available products used in over 75 different types of procedures, there were only 17 different isotopes used as radioactive agents in these products.
- Of these 17 different isotopes, 12 are customarily administered to outpatients, and at 91.5 %, the isotope Tc-99m is by an overwhelming margin the most likely isotope to be administered.

CONTENTS

1.0 INTRODUCTION

1.1 Motivation

Each day in the U.S., over 39,000 medical procedures are performed that use radioactive isotopes. The overwhelming majority of these procedures are diagnostic in nature, and performed on an out-patient basis, i.e., most of these patients are free to move about in less than 24 hours after receiving the initial dose. Within that time period, most of these patients, traveling either as pedestrians or as passengers in vehicles, may cause alarms in various handheld or roadside radiation detectors. As local governments, as well as the Department of Homeland Security (DHS), Customs and Border Protection (CBP), implements their task to detect the illicit transport of nuclear material, the presence of radiation detectors will increase. The information on medical isotopes compiled in this survey should help in estimating the frequency and signatures of these “innocent” medical-based alarms.

1.2 Objective

The objective of this survey was to obtain accurate, up-to-date information about the radioactive isotopes used in the U.S. for medical procedures. The categories of data sought were the total number of such procedures, the specific types of procedures, the specific radioisotopes used in these procedures, and the dosage administered per procedure. The results presented in this Preliminary Survey do not represent an exhaustive search, and thus, should be considered as initial estimates. However, because the data used to obtain these preliminary results was of high quality, the results are expected to be reasonably accurate.

1.3 Data Sources

The data collected for this Preliminary Survey was obtained from the three sources (listed in the Reference section, below). These sources represent the Medical community, the Business & Finance community, and the Applied Nuclear Science community. Because these professions have been compiling information for different purposes, data from all three sources were needed to cover the range of our objectives.

To attain a single, comprehensive and consistent set of data, the information from the above three sources was compiled, assessed, pruned, and then merged to give the results shown in the body of this report. This information is used as an initial database for estimating the number and characteristic signature of medical incidents that may be detected by radiation portal monitors.

A summary of the Preliminary Survey results is given in Table 1, and displayed as distributions in Figure 2-1. The sets of data used to obtain this summary are listed in Table 2, Table 3, and Table 4 in the Data Tables section at the end of this report. Background discussion and more detailed comments about these sets of data are given in the Sections 2, 3, and 4 below.

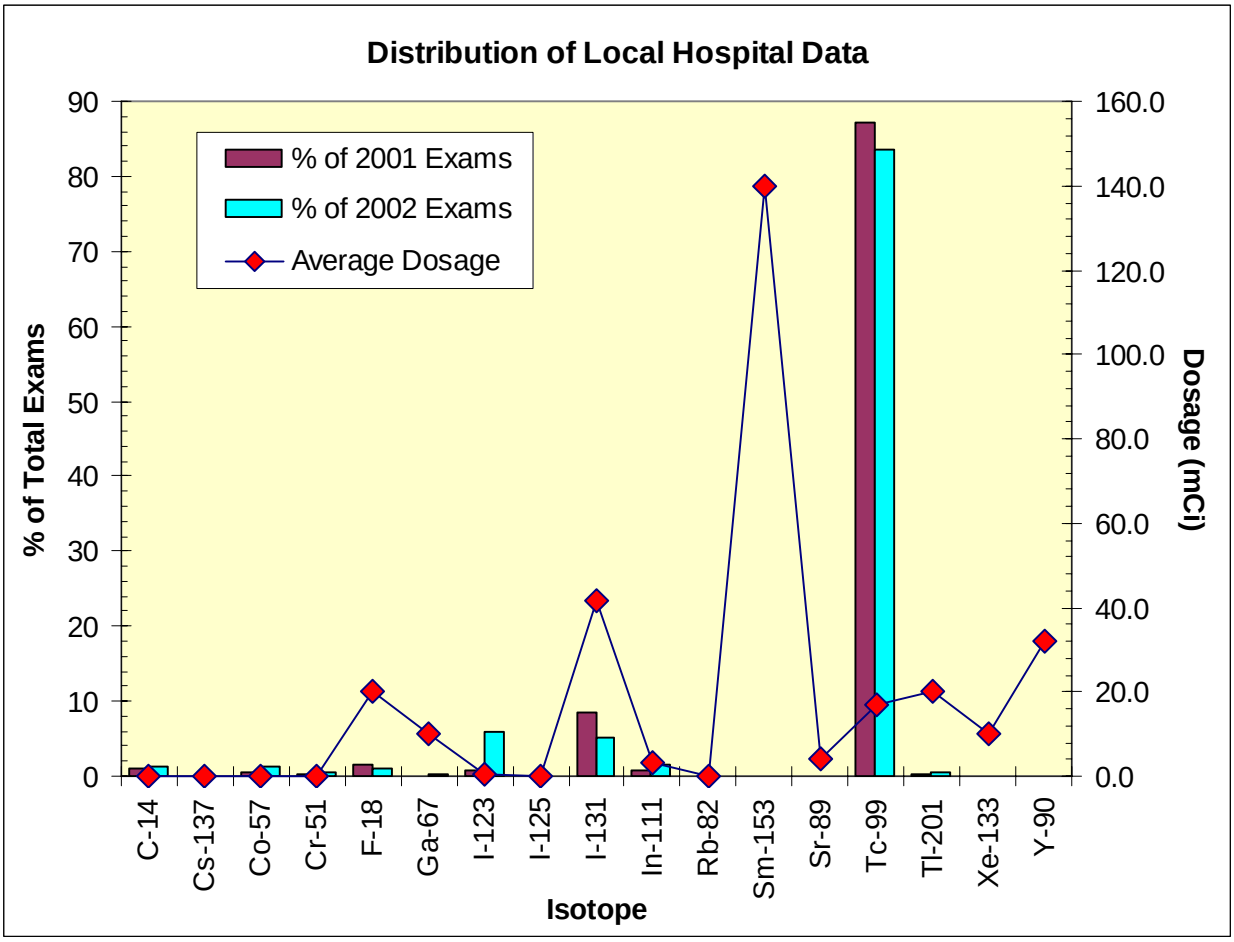
2.0 MEDICAL DATA

The data from the Medical community were obtained from the records of the Nuclear Medicine Department of a local hospital in Richland WA (Ref.1). The period covered by these records was from January 01, 2001 through November 23, 2002. The original data were listed in two different types of data records: Statistical Report sheets and Exam Master File sheets. The Statistical Report sheets listed the Exam Types, the number of each Exam Type given over the period of the report, and the Patient Type (e.g. In-Patient, Out-Patient, etc.). The Exam Master File sheets listed Exam Reference Numbers (Exam R#) for each Exam Type, the Radiopharmaceutical Product used for each Exam R#, and the range of activity for each Radiopharmaceutical Product. The data from these original records were cross-referenced, checked for consistency, and merged into the set of data listed in Table 2 (listed in the Data Tables section at the end of this report).

From the data listed in Table 2, it is seen a total of 2797 exams were performed on 2694 patients (i.e., 1.04 exams per patient) over the base-year period of 1 January 2001 – 31 December 2001. The breakdown of these exams was 39.24 % male, 58.20 % female, and 2.41 % pediatric. The majority of these exams (91 %) were administered to out patients.

Table 1: Summary of Prelimary Survey Results

Isotope	Average Adminis-tered Activity (MBq)	Half Life	Organ	Percent of 2001 Dosages at local hospital (2797 Total)	Percent of 2002 Dosages at local hospital (2352 Total in 11 months)	*Percent of Procedures Administered in U.S. during 2001 (14.39 million Total)	*Annual Procedures in U.S. per ten thousand population for 2001
C-14	0.0370	5,700 yr	Kidneys, Bladder	1.07	1.19	1.89	9.7
Cs-137	**N/A**	30.17 yr		0.07	0.04	Not Analyzed	Not Analyzed
Co-57	0.0222	270 days	Bladder, Liver, Kidneys	0.61	1.40	1.07	5.5
Cr-51	2.775	27.7 days	Liver	0.25	0.47	0.35	1.8
F-18	740.0	109 min	Bones, Bladder	*1.43	*1.00	2.02	10.3
Ga-67	370.0	78 hr	Intestines, Marrow	0.11	0.34	0.19	1.0
I-123	11.10	13.3 hrs	Thyroid, Kidneys	0.86	5.82	0.03	0.2
I-125	**N/A**	60 day	Thyroid, Spleen, Lungs	0.00	0.00	Insufficient Data	Insufficient Data
I-131	1546.7	8 day	Thyroid, kidneys	8.54	5.19	0.34	1.7
In-111	119.33	68 hrs	Liver, Marrow, Spleen	0.89	1.49	1.40	7.2
Rb-82m	**N/A**	6.2 hrs		0.00	0.00	Insufficient Data	Insufficient Data
Sm-153	5180.0	46.8 hrs		0.04	0.04	0.39	2.0
Sr-89	148.0	50.5 day		0.04	0.00	0.39	2.0
Tc-99m	625.71	6 hrs	Liver, Spleen, Marrow, Kidneys, Bladder, Stomach, Bones	87.06	83.55	91.51	467.7
Tl-201	740.00	73.5 hrs	Heart, Lungs	0.36	0.43	0.42	2.2
Xe-133	370.00	5 day	Lungs	0.00	0.00	Insufficient Data	Insufficient Data
Y-90	1184.0	64.1 hrs		0.00	0.04	Insufficient Data	Insufficient Data
Footnotes				*Estimated	*Estimated	*From Market Data	*Using 2000 Census, 281.42 million



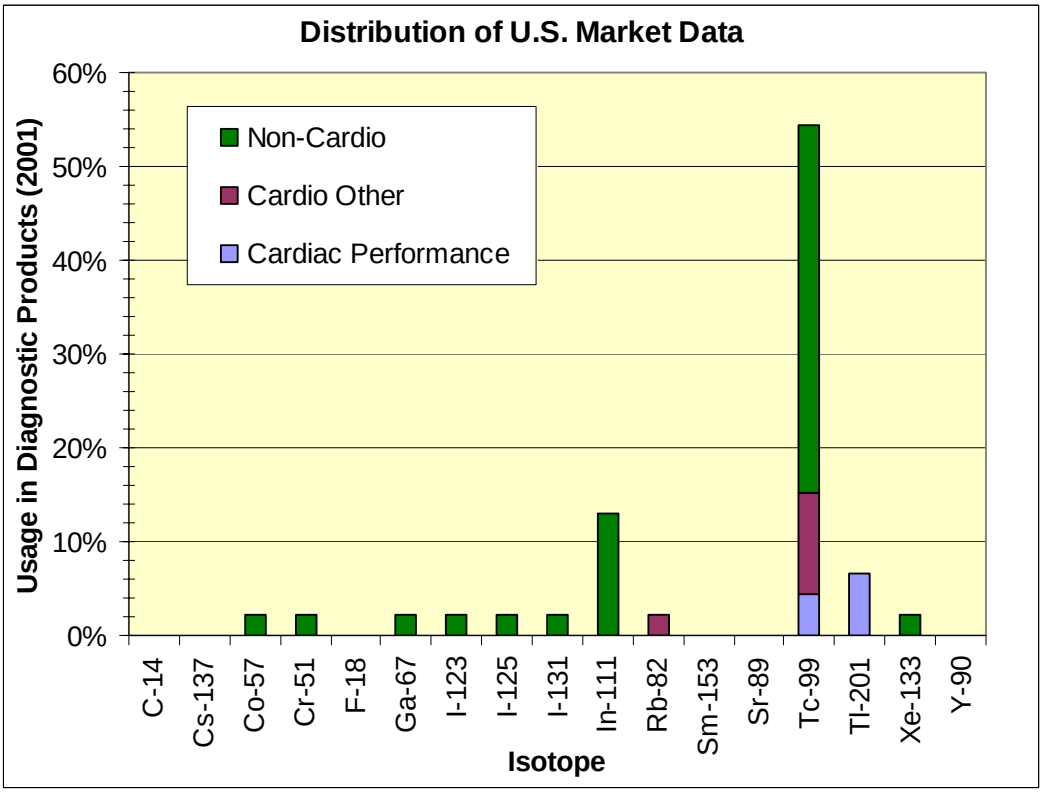


Figure 2-1: FIGURES 1a(Top) and 1b (Bottom).

3.0 BUSINESS & FINANCE DATA

The data from the Business & Finance community were taken from a recent report by Frost & Sullivan entitled “U.S. Radiopharmaceuticals Markets.” (Ref.2). The overall objective of this report was to assess the current state of the various sectors of U.S. markets, and predict the behavior of the individual market sectors in the near future. The data in the report covers the eleven-year period from 1998 through 2008; where the 2001 data are used as the base year. The data listed for 2002 – 2008 were extrapolated from the earlier data by using reasonably sound economic assumptions, and, depending on the particular market sector, amounted to compound annual growth rates from approximately 2 % to 6 %.

Because of the financial perspective of this report, the data from this source is organized according to the dominant market sectors, with emphasis on market-place drivers and projected revenues. Medical procedure types define the market sectors, where the topmost major division of the overall market is made between Diagnostic and Therapeutic procedures. These two major sectors are further broken down into their dominant components of three diagnostic sub- sectors and two therapeutic sub-sectors. These sub-sectors are Diagnostic-Cardiac, Diagnostic-PET/FDG, Diagnostic-Other, and Therapeutic-Bone and Therapeutic-Thyroid. All other therapeutic procedures, such as brachytherapy seeds (Cesium-137 implants) and Rhenium-188 therapy (following vascular stents for prevention of restenosis) were not considered significant for the purposes of this report; and thus were omitted. For each one of the five sub-sectors, we were able to obtain (or deduce) from the information in this report data on the total number of procedures, the dominant products used for these procedures, and the isotope used in each of the products. This information was distributed throughout the report as textual comments or in various tables.

According to this report, there were a total of 14.19 E+6 Diagnostic procedures compared to approximately 0.20 E+6 Therapeutic procedures performed in the U.S during 2001. The total number of Diagnostic procedures consists of three main categories: 0.29 E+06 FDG (Pet Scans), 5.83 E+06 Cardiology, and 8.08 E+06 Other. The detailed information used to correlate and cross-reference the number of procedures in each of these categories to specific isotopes is summarized in Table 3 (listed in the Data Tables section at the end of this report).

4.0 APPLIED NUCLEAR SCIENCE DATA

The data from the field of Applied Nuclear Science was obtained from R.E. Schenter in the form of a private communication. Dr. Schenter has compiled a comprehensive list of 111 isotopes and their applications from the field of Nuclear Medicine. Note that most of these isotopes have been used in medical research projects, and are not commercially produced. Therefore they are unlikely to be seen at ports of entry into the U.S. Nevertheless, this list is important to have as a reference because some of these isotopes may eventually find their way into the commercial markets.

5.0 REFERENCES

1. VanderMalle, M., *Hospital Statistics, Private Communication*. 2002.
2. Frost_&_Sullivan, *U.S. Pharmaceutical Markets*. 2002.
3. R.E. Schenter, Private Communication

6.0 DATA TABLES

Table 2: Medical Data from Ref.1

Exam R#	Exam Name	Radiopharmaceutical Product	Isotope	Activity (mCi)	Exams in 2001	Exams in 2002
1	ACUTE	Acutect	Tc-99	20.0	2	
2	IN-111 Zevalin	IN-lll ZEVALIN	In-111	5.00	0	1
3	Y-90 Zevaline	Y-90 Zevaline	Y-90	10.0 -- 32.0	0	1
4	ADENOSINE Heart Perf.	MYOVIEW	Tc-99	22.0	204	151
5	BONE Marrow	Sulfur Colloid	Tc-99	10.0 -- 15.0	2	4
6	BONE SCAN	MDP	Tc-99	30.0	226	184
7	BONE SCAN	MDP	Tc-99	30.0	499	416
8	BONE SPECT	MDP	Tc-99	30.0	65	49
9	BONE Three Phase	MDP	Tc-99	30.0	58	57
10	BRAIN Imaging w/ Flow	D.T.P.A.	Tc-99	25.0	13	
11	BRAIN	Ceretec	Tc-99	25.0	51	33
12	BREAST Lymphoscintigr	Sulfur Colloid	Tc-99	0.90 -- 1.50	20	21
13	CESIUM 137 Implant	CESIUM 137 Seeds	Cs-137	???	2	1
14	CISTERNOGRAPHY	DTPA	In-111	1.00	3	4
15	DICOPAC	Co-58/-57		0.0006	10	
16	DMSA	D.M.S.A	Tc-99	4.00	0	2
17	DOBUTAMINE Heart Perf.	Cardiolite	Tc-99	22.0	14	4
18	G.E. Reflux	Sulfur Colloid	Tc-99	0.50	9	4
19	Gastric Emptying	Sulfur Colloid	Tc-99	1.00	44	57
20	GATED	Tc99m-	Tc-99	20.0 -- 30.0	39	13
21	GI Blood Loss	U1traTag RBC	Tc-99	20.0	19	19
22	HEPATOBiliary	Hepatolite	Tc-99	5.00	20	32
23	HEPATOBILIARY	Hepatolite	Tc-99	5.00	187	180
24	LIVERHEMANgioma	U1traTag RBC	Tc-99	20.0 -- 30.0	1	1
***25						
26	LIVER/SPLEEN	Microlite	Tc-99	6.00	4	6
27	LUNG	MAA	Tc-99	6.00	42	37
28	LUNG VENT./DTPA	D.T.P.A.	Tc-99	35.0 -- 40.0	41	35
29	LUNG VENT./ Xe133		Xe-133	10.0	0	
30	LYMPHOSCINTGRAPHY	Microlite	Tc-99	1.00	5	3
31	MECKELS	Tc99m	Tc-99	10.0	1	6
32	MIBI Rest	Cardiolite	Tc-99	22.0	2	60
33	MIBI Stress	Cardiolite	Tc-99	22.0	0	43
34	MIBI Stress	Cardiolite	Tc-99	22.0	1	20
35	MYOVIEW Persanine	MYOVIEW	Tc-99	22.0	1	
36	MYOVIEW Rest	MYOVIEW	Tc-99	22.0	422	279
37	MYOVIEW Stress	MYOVIEW	Tc-99	22.0	217	123
38	NEOTECT	NeoTect	Tc-99	15.0 -- 20.0	1	
39	PARATHYROID	Cardlolite	Tc-99	25.0	12	13

Exam R#	Exam Name	Radiopharmaceutical Product	Isotope	Activity (mCi)	Exams in 2001	Exams in 2002
40	PERITONEAL	Sulfur Colloid	Tc-99	3.00 -- 5.00	1	
41	PY-TEST C14 UREA	C-14 UREA	C-14	0.001	30	28
42	PYP INFARCT	PYP	Tc-99	25.0	0	0
43	QUADRAMET	Quadremet	Sm-153	36.0 -- 140.0	1	1
44	RED Cell Mass	Cr-51	Cr-51	0.075	7	11
45	RENAL W/ LASIX	MAG3	Tc-99	6.00	20	24
46	RENOGRAM	MAG3	Tc-99	6.00	9	4
47	RENOGRAM w/ Captopril	MAG3	Tc-99	6.00	18	14
48	SCHILLINGS	Co-57	Co-57	0.0005	7	33
49	SCINTIMAMMOGRAPHY	Cardiolite	Tc-99	25.0	0	1
50	SHUNT Patency V/P	D.T.P.A.	Tc-99	1.00	19	6
51	SPECT Miscellaneous	Ga-67	Ga-67	???	0	1
52	STRONTIUM 89 RX	Metastron	Sr-89	4.00	1	
53	THYROID ABLATION	I-131	I-131	30.0	18	13
54	THYROID CA ABLATION	I-131	I-131	34.0 -- 150.0	2	4
55	THYROID Hyperthyroidism	I-131	I-131	5.00 -- 25.0	48	15
56	THYROID SCAN	Tc99m	Tc-99	5.00	143	63
57	THYROID SCAN I-123	I-123 Caps	I-123	0.40	13	75
58	THYROID Uptake	I-131	I-131	0.004 -- 0.016	154	67
59	THYROID Uptake I-123	I-123 Caps	I-123	0.20	11	62
60	THYROID WB Iodine	I-131	I-131	3 -- 4.00	17	23
61	TL201 REST	Tl-201	Tl-201	4.00	3	7
62	TL201 24Hour SPECT	Tl-201	Tl-201	???	0	0
63	TL201 ADENOSINE	Tl-201	Tl-201	3.50	0	0
64	TL201 PERSANTINE	TI-201	TI-201	3.50	0	0
65	TL201 Reinjection	Tl-201	Tl-201	1.00 -- 2.00	4	2
66	TL201 Stress Treadmill	TI-201	Tl-201	3.50	3	1
67	TRACER SENT OUT	Tc99m	Tc-99	20.00	0	0
68	Tumor Localization -M	Cardiolite	Tc-99	25.00	0	0
69	Tumor Localization -G	Ga-67	Ga-67	6.00 -- 10.0	3	7
70	Tumor Localization -O	In-111-0ctreoScan	In-111	6.00	9	9
***71						
72	Tumor Localization -T	Tl-201	Tl-201	3.50	0	0
73	Tumor LOCALZ. CEA-SCA	SEA-SCAN	Tc-99	25.00	0	0
74	URETERAL Reflux	Tc99m	Tc-99	1.00	1	1
75	WHITE Cell / Indium	In-111 WBC	In-111	0.50 -- 0.90	13	21
76	WHITE Cell / TC-HMPAO	Ceretec	Tc-99	8.00 -- 25.0	2	0
***77	PET	"FDG"	F-18	8.00 -- 20.0	0	120

Table 3: Summary of Data from 2001 U.S. Market Survey of Products by Ref.2

Market	Product No.	Product Name			
			Isotope	Manufacturer	Application (See Notes)
Diagnostic - Cardiac	1	Cardiolite	Tc-99	BMS	Cardio/Diag - MP
	2	Myoview	Tc-99	Amer.	Cardio/Diag - MP
	3	Thallium-201	Tl-201	BMS	Cardio/Diag - MP
	4	Thallium-201	Tl-201	Amer.	Cardio/Diag - MP
	5	Thallium-201	Tl-201	Mall.	Cardio/Diag - MP
	6	Tc-99 PYP	Tc-99	Amer.	Cardio/Diag - BP
	7	Phosphotec	Tc-99	Brac.	Cardio/Diag - BP
	8	Technescan PYP	Tc-99	Mall.	Cardio/Diag - BP
	9	CIS-Pyro	Tc-99	CIS	Cardio/Diag - BP
	10	Pyrolite	Tc-99	CIS	Cardio/Diag - BP
	11	Cardiogen	Rb-82	Brac.	Cardio/Diag - MV
Diagnostic - Other	12	Sodium Chromate	Cr-51	Mall.	RBC
(Tier-1 Suppliers)	13	*no name*	Ga-67	Amer., BMS, Mall.	Soft Tissue Tumor / Lymphoma
	14	Sodium Iodine	I-123	Amer., Mall.	Thyroid
	15	Human Serum Albmn	I-125	Mall.	Blood / Plasma Vol.
	16	Chloride	In-111	Amer., Mall.	Labelling Agent
	17	Oxine	In-111	Amer.	WBC / platelets
	18	Pentetreotide	In-111	Mall.	Neuroendoctrine Tumors
	19	Bicisate	Tc-99	BMS	Brain
	20	Exametazine	Tc-99	Amer.	Cerebral Blood Flow / WBC
	21	MAA	Tc-99	Mall.	Lung
	22	Medronate	Tc-99	Amer., Mall.	Skeletal / Bone
	23	Mertiatide	Tc-99	Mall.	Renal
	24	Oxidronate	Tc-99	Amer., Mall.	Bone
	25	Pentetate	Tc-99	Amer., Mall.	Kidney / Brain
	26	Pyrophosphate	Tc-99	Amer., Mall.	Skeletal / Cardiac
	27	RBC	Tc-99	Mall.	Blood Pool / GI
	28	Sestamibi	Tc-99	BMS	Cardiac / Breast
	29	Sdm. Glucoheptonate	Tc-99	Mall.	Kidney / Brain
	30	Succimer	Tc-99	Amer.	Renal Parenchymal
	31	Sulfur Colloid	Tc-99	Amer.	RC
	32	*no name*	Xe-133	Amer., BMS, Mall.	Pulmonary / Lung
Diagnostic - Other	33	Cyanobalamin	Co-57	Brac.	Pernicious Anemia

(Tier-2 Suppliers)	34	Capromab Pendetide	In-111	Cytg	Prostate Cancer
	35	Satumomab Pendetide	In-111	Cytg	Colorectal / Ovarian Cancer
	36	Pentetreotide	In-111	CIS	CSF Kinetics
	37	MIBG	I-131	CIS, Drax.	Pheochromocytomas / Neuroblastoma
	38	Apcitide	Tc-99	Brlx	Acute Venous Thrombosis
	39	Arcitumomab	Tc-99	Immu	Colorectal Cancer
	40	Depreotide	Tc-99	Brlx	Pulmonary Mass
	41	Disofenin	Tc-99	CIS	Hepatobiliary
	21	MAA	Tc-99	Brac., CIS	Lung / Perfusion
	42	Mebrofenin	Tc-99	Brac., CIS	Hepatobiliary
	25	Pentetate	Tc-99	Brac., CIS, Drax.	Kidney / Brain
	26	Pyrophosphate	Tc-99	Brac., CIS	Skeletal / Cardiac
	29	Sodium Glucoheptonate	Tc-99	Drax.	Kidney / Brain
	31	Sulfur Colloid	Tc-99	CIS	RC
	32	*no name*	Xe-133	Drax.	Lung / Pulmonary
Diagnostic - PET	43	FDG	F-18		PET Diagnostic
Therapeutic-Bone	44	Quadramet	Sm-153		Bone Pain Palliation
(55-60% of Therapy Sector)	45	Metastron	Sr-89		Bone Pain Palliation
Therapeutic-Thyroid	46	*no name*	I-131		Hyperthyroidism/Thyroid Cancer
(40-45% of Therapy Sector)					

NOTES:

Products listed Market Sector, then top-down by percent.

Some products are supplied by more than one manufacturer.

Application Key

MP => Myocardial Perfusion
BP => Blood Pool
MV => Myocardial Viability
RBC => Red Blood Cells
WBC => White Blood Cells
GI => Gastrointestinal
RC => Reticuloendothelial Cells
CSF =>

Table 4: Medical Isotope Application Data from Ref.3.

ISOTOPE	Half-Life	APPLICATIONS
Ac-225	10.0d	Monoclonal antibody attachment used for cancer treatment (RIT), also parent of Bi-213.
Ac-227	21.8y	Parent of Ra-223 (Monoclonal antibody attachment used for cancer treatment (RIT).
Am-241	432y	Osteoporosis detection, heart imaging.
As-72	26.0h	Planar imaging, SPECT or PET.
As-74	17.8d	Positron-emitting isotope with biomedical applications.
At-211	7.21h	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT), used with F-18 for in vivo studies.
Au-198	2.69d	Cancer treatment using mini-gun (B), treating ovarian, prostate, and brain cancer.
B-11	Stable	Melanoma and brain tumor treatment.
Be-7	53.2d	Used in berylliosis studies.
Bi-212	1.10h	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT), cellular dosimetry studies.
Bi-213	45.6m	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT).
Br-75	98m	Planar imaging, SPECT or PET (C).
Br-77	57h	Label radiosentizers for Te quantization of hypoxia in tumors, and monoclonal antibody labeling.
C-11	20.3m	Radiotracer in PET scans to study normal/abnormal brain functions.
C-14	5730y	Radiolabeling for detection of tumors (breast, et al.).
Ca-48	Stable	
Cd-109	462d	Cancer detection (C), pediatric imaging (C).
Ce-139	138d	Calibrates high-purity germanium gamma detectors <medical application?>.
Ce-141	32.5d	Gastrointestinal tract diagnosis, measuring regional myocardial blood flow.
Cf-252	2.64y	Cervical, melanoma, brain cancer treatment.
Co-55	17.5h	Planar imaging, SPECT or PET (B). Used in PET imaging of damaged brain tissue after stroke.
Co-57	272d	Gamma camera calibration, should be given high priority, radiotracer in research and a source for X-ray fluorescence spectroscopy.
Co-60	5.27y	Teletherapy (destroy cancer cells), disinfect surgical equipment and medicines, *external radiation cancer therapy* (E).
Cr-51	27.7d	Medical, cell labeling and dosimetry.
Cs-130	29.2m	Myocardial localizing agent.
Cs-131	9.69d	Intracavity implants for radiotherapy.
Cs-137	30.2y	Blood irradiators, PET imaging, tumor treatment.
Cu-61	3.35h	Planar imaging, SPECT or PET (B).
Cu-62	4.7m	Positron emitting radionuclide (B), cerebral and myocardial blood flow used As-a tracer in conjunction with Cu 64 (B).
Cu-64	12.7h	PET scanning (C), planar imaging (C), SPECT imaging (C) dosimetry studies (C), cerebral and myocardial blood flow (C), used with Cu-62 (C), treating of colorectal cancer.
Cu-67	61.9h	Cancer treatment/diagnostics, monoclonal antibodies, radioimmunotherapy, planar imaging, SPECT or PET.
Dy-165	2.33h	Radiation synovectomy, rheumatoid arthritis treatment.
Eu-152	13.4y	Medical.
Eu-155	4.73y	Osteoporosis detection.

ISOTOPE	Half-Life	APPLICATIONS
F-18	110m	Radiotracer for brain studies (C), PET imaging (C).
Fe-55	2.73y	Heat source <medical application?>.
Fe-59	44.5d	Medical.
Ga-64	2.63m	Treatment of pulmonary diseases ending in fibrosis of lungs.
Ga-67	78.3h	Imaging of abdominal infections (C), detect Hodgkins/non-Hodgkins lymphoma (C), used with In-111 for soft tissue infections and osteomyelitis detection (C), evaluate sarcoidiodis and other granulomaous diseases, particularly in lungs and mediastiusim (C).
Ga-68	68.1m	Study thrombosis and atherosclerosis, PET imaging, detection of pancreatic cancer, attenuation correction.
Gd-153	242d	Dual photon source, osteoporosis detection, SPECT imaging.
Ge-68	271d	PET imaging.
H-3	12.3y	Labeling, PET imaging.
I-122	3.6m	Brain blood flow studies.
I-123	13.1h	Brain, thyroid, kidney, and myocardial imaging (C), cerebral blood flow (ideal for imaging) (C), neurological disease (Alzheimer's) (C).
I-124	4.17d	Radiotracer used to create images of human thyroid, PET imaging.
I-125	59.9d	Osteoporosis detection, diagnostic imaging, tracer for drugs, monoclonal antibodies, brain cancer treatment (I-131 replacement), SPECT imaging, radiolabeling, tumor imaging, *mapping of receptors in the brain (A), interstitial radiation therapy (brachytherapy) for treatment of prostate cancer (E).*
I-131	8.04d	Lymphoid tissue tumor/hyperthyroidism treatment (C), antibody labeling (C), brain biochemistry in mental illness (C), kidney agent (C), thyroid problems (C), alternative to Tl-201 for radioimmunotherapy (C), imaging, cellular dosimetry, scintigraphy, treatment of graves disease, treatment of goiters, SPECT imaging, *treatment of prostate cancer, treatment of hepatocellular carcinoma, treatment of melanoma (A), locate osteomyelitis infections (A), radiolabeling (A), localize tumors for removal (A), treatment of spinal tumor (A), locate metastatic lesions (A), treAt-neuroblastoma (A), internal (systemic) radiation therapy (E), treatment of carcinoma of the thyroid (E).*
I-132	2.28h	Mapping precise area of brain tumor before operating.
In-111	2.81d	Detection of heart transplant rejection (C), imaging of abdominal infections (C), antibody labeling (C) cellular immunology (C), used with Ga-67 for soft tissue infection detection and ostemyelitis detection (C), concentrates in liver, kidneys (C), high specific activity (C), white blood cell imaging, cellular dosimetry, myocardial scans, treatment of leukemia, imaging tumors.
In-115m	4.49h	Label blood elements for evaluating inflammatory bowel disease.
Ir-191m	6s	Cardiovascular angiography.
Ir-192	73.8d	Implants or "seeds" for treatment of cancers of the prostate, brain, breast, gynecological cancers.
Kr-81m	13.3s	Lung imaging.
Lu-177	6.68d	Heart disease treatment (restenosis therapy), cancer therapy.
Mn-51	46.2m	Myocardial localizing agent.
Mn-52	5.59d	PET scanning.
Mo-99	65.9h	Parent for Tc-99m generator used for brain, liver, lungs, heart imaging.
N-13	9.97m	PET imaging, myocardial perfusion.
Nb-95	35d	Study effects of radioactivity on pregnant women and fetus, myocardial tracer, PET imaging.
O-15	122s	Water used for tomographic measuring of cerebral blood flow (C), PET imaging (C),

ISOTOPE	Half-Life	APPLICATIONS
		SPECT imaging.
Os-191	15.4d	Parent for Ir-191m generator used for cardiovascular angiography.
Os-194	6.00y	Monoclonal antibody attachment used for cancer treatment (RIT).
P-32	14.3d	Polycythaemia Rubra Vera (blood cell disease) and leukemia treatment, bone disease diagnosis/treatment*, SPECT imaging of tumors (A), pancreatic cancer treatment (A), radiolabeling (A).*
P-33	25d	Labeling.
Pb-203	2.16d	Planar imaging, SPECT or PET (used with Bi-212) (B), monoclonal antibody immunotherapy (B), cellular dosimetry.
Pb-212	10.6h	Radioactive label for therapy using antibodies, cellular dosimetry.
Pd-103	17d	Prostate cancer treatment.
Pd-109	13.4h	Potential radiotherapeutic agent.
Pu-238	2.3y	Pacemaker (no Pu-236 contaminants).
Ra-223	11.4d	Monoclonal antibody attachment (alpha emitter) used for cancer treatment (RIT).
Ra-226	1.60e3y	Target isotope to make Ac-227, Th-228, Th-229 (Parents of alpha emitters used for RIT).
Rb-82	1.27m	Myocardial imaging agent, early detection of coronary artery disease, PET imaging, blood flow tracers.
Re-186	3.9d	Cancer treatment/diagnostics, monoclonal antibodies, bone cancer pain relief, treatment of rheumatoid arthritis, treatment of prostate cancer, treating bone pain.
Re-188	17h	Monoclonal antibodies, cancer treatment.
Rh-105	35.4h	*Potential therapeutic applications: target neoplastic cells (e.g., small cell lung cancer) (A), labeling of molecules and monoclonal antibodies (A).*
Ru-97	2.89d	Monoclonal antibodies label (C), planar imaging (C), SPECT or PET techniques (C), gamma-camera imaging.
Ru-103	39d	Myocardial blood flow, radiolabeling mircospheres, PET imaging.
S-35	87.2d	Nucleic acid labeling, P-32 replacement, cellular dosimetry.
Sc-46	84d	Regional blood flow studies, PET imaging.
Sc-47	3.34d	Cancer treatment/diagnostics (F), monoclonal antibodies (F), radioimmunotherapy (F).
Se-72	8.4d	Brain imaging, generator system with As-72, monoclonal antibody immunotherapy.
Se-75	120d	Radiotracer used in brain studies, scintigraphy scanning.
Si-28	Stable	Radiation therapy of cancer.
Sm-145	340d	Brain cancer treatment using I-127 (D).
Sm-153	2.00d	Cancer treatment/diagnostics (C), monoclonal antibodies (C), bone cancer pain relief (C), higher uptake in diseased bone than Re-186 (C), treatment of leukemia.
Sn-117m	13.6d	Bone cancer pain relief.
Sr-85	65.0d	Detection of focal bone lesions, brain scans.
Sr-89	50d	Bone cancer pain palliation (improves the quality of life), cellular dosimetry, treatment of prostate cancer, treatment of multiple myeloma, osteoblastic therapy, potential agent for treatment of bone metastases from prostate and breast cancer (E).
Sr-90	29.1y	Generator system with Y-90 (B), monoclonal antibody immunotherapy (B).
Ta-178	9.3m	Radionuclide injected into patients to allow viewing of heart and blood vessels.
Ta-179	1.8y	X-ray fluorescence source and in thickness gauging (might be a good substitute for Am-241).
Ta-182	115d	Bladder cancer treatment, internal implants.
Tb-149	4.13h	Monoclonal antibody attachment used for cancer treatment (RIT).

ISOTOPE	Half-Life	APPLICATIONS
Tc-96	4.3d	Animal studies with Tc-99m.
Tc-99m	6.01h	Brain, heart, liver (gastoenterology), lungs, bones, thyroid, and kidney imaging (C), regional cerebral blood flow (C), equine nuclear imaging (C), antibodies (C), red blood cells (C), replacement for Tl-201 (C).
Th-228	720d	Cancer treatment, monoclonal antibodies, parent of Bi-212.
Th-229	7300y	Grandparent for alpha emitter (Bi-213) used for cancer treatment (RIT), parent of Ac-225.
Tl-201	73.1h	Clinical cardiology (C), heart imaging (C), less desirable nuclear characteristics than Tc-99m for planar and SPECT imaging (C), myocardial perfusion, cellular dosimetry.
Tm-170	129d	Portable blood irradiations for leukemia, lymphoma treatment, power source.
Tm-171	1.9y	Medical.
W-188	69.4d	Cancer treatment, monoclonal antibodies, parent for Re-188 generator.
Xe-127	36.4d	Neuroimaging for brain disorders, research for variety of neuropsychiatric disorders, especially schizophrenia and dementia, higher resolution SPECT studies with lower patient dose, lung imaging (some experts believe it is superior to Xe-133 in inhalation lung studies).
Xe-133	5.25d	Lung imaging (C), regional cerebral blood flow (C), liver imaging (gas inhalation) (C), SPECT imaging of brain, lung scanning, lesion detection.
Y-88	107d	Substituted for Y-90 in development of cancer tumor therapy.
Y-90	64h	Internal radiation therapy of liver cancer (C), monoclonal antibodies (C), Hodgkins disease, and hepatoma (C), cellular dosimetry, treating rheumatoid arthritis, treating breast cancer, *treatment of gastrointestinal adenocarcinomas (A).*
Y-91	58.5d	Cancer treatment (RIT), cellular dosimetry.
Yb-169	32d	Gastrointestinal tract diagnosis.
Zn-62	9.22h	Parent of Cu-62, a positron-emitter, used for the study of cerebral and myocardial blood flow.
Zn-65	244d	Medical.
Zr-95	64.0d	Medical.

NOTES:

A = June 1996 SNM Abstracts
B = Holmes 91
C = Herac 89
D = Fairchild 87
E = Everyone's Guide to Cancer Therapy (Dollinger, Rosenbaum, Cable), 1991
F = SNM (Society of Nuclear Medicine)