Radionuclides and Radiopharmaceuticals for 2005

The breakneck rate of change to which we have become accustomed in the scientific world has not been reflected in the number of changes in available radionuclides and radiopharmaceuticals between my last compilation in 2003 (*J Nucl Med.* 2003;44[6]:27N–31N) and the current lists. Economic and regulatory issues have not kept pace with radiopharmaceutical science.

Gone is radiolabeled hippuran (labeled with ^{123}I or ^{131}I), a stalwart of renal diagnosis since 1961, because of the excellent physical and biologic properties of ^{99m}Tc-mertiatide (MAG3). ^{99m}Tc-lidofenin has disappeared as a hepatobiliary agent, leaving ^{99m}Tc-labeled disofenin and mebrofenin on the market.

^{131}I-tositumomab finally passed U.S. Food and Drug Administration (FDA) review as another labeled antibody against lymphocyte antigen CD20 (as is ^{90}Y-ibritumomab tiuxetan) for the therapy of lymphoma. ^{99m}Tc-fanolesomab, an antibody directed against granulocyte antigen CD15, has been approved by the FDA for the diagnosis of appendicitis in patients age 5 and over with equivocal symptoms and signs.

Although PET agents such as ^{11}C-carbon monoxide, ^{11}C-flumenazil, ^{11}C-mespiperone, ^{11}C-methionine, ^{11}C-raclopride, ^{11}C-acetate, ^{18}F-fluorodopa, ^{13}N-ammonia, and ^{15}O-water are now being compounded under the state-regulated practice of medicine and pharmacy, these are not widely available outside of certain research institutions and so do not appear on the list.

I have added 2 radiopharmaceuticals classified as "devices" for brachytherapy by the FDA: ^{90}Y-microspheres (for unresectable hepatocellular carcinoma) and ^{125}I-3-iodo-4-hydroxybenzenesulfonate (for recurrent malignant glioma).

A number of new radionuclides appear on this list, such as ^{7}Be, ^{32}Si, and ^{44}Ti, produced by the U.S. Department of Energy (DOE), as well as the radioisotopes of plutonium, uranium, and thorium available from the

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TABLE 1
Commercially Available Radiopharmaceuticals, 2005

^{14}C-urea
^{57}Co-cyanocobalamin
^{51}Cr-sodium chromate
^{18}F-sodium fluoride
^{18}F-fluorodeoxyglucose (FDG)*
^{67}Ga-gallium citrate
^{111}In-capromab pendetide (PMSA)†
^{111}In-ibritumomab tiuxetan (CD20)†
^{111}In-indium chloride
^{111}In-indium oxyquinoline (oxine)*
^{111}In-pentetate (DTPA)*
^{111}In-pentetreotide (SRS)†
^{123}I-iobenguane (MIBG)*
^{123}I-sodium iodide
^{125}I-iodinated albumin (HSA)*
^{125}I-3-iodo-4-hydroxybenzenesulfonate**
^{125}I-sodium iothalamate
^{131}I-iobenguane
^{131}I-iodinated albumin
^{131}I-sodium iodide
^{131}I-6-β-iodomethyl-19-norcholesterol††
^{131}I-tositumomab
^{32}P-chromic phosphate (suspension)
^{32}P-sodium phosphate
^{82}Rb-rubidium chloride
^{153}Sm-samarium lexidronam (EDTMP)*
^{89}Sr-strontium chloride
^{99m}Tc-apcitide (GPIIa/IIIb)†
^{99m}Tc-arcitumomab (CEA)†
^{99m}Tc-bicisate dihydrochloride (ECD)*
^{99m}Tc-disofenin (DISIDA)*
^{99m}Tc-exametazime (HMPAO)*
^{99m}Tc-fanolesomab (CD15)†
^{99m}Tc-gluceptate
^{99m}Tc-macroaggregated albumin (MAA)*
^{99m}Tc-mebrofenin
^{99m}Tc-medronate (MDP)*
^{99m}Tc-mertiatide (MAG3)*
^{99m}Tc-oxidronate (HDP)*
^{99m}Tc-pentetate (DTPA)*
^{99m}Tc-sodium pertechnetate
^{99m}Tc-pyrophosphate (PYP)*
^{99m}Tc-red blood cells§
^{99m}Tc-sestamibi
^{99m}Tc-succimer (DMSA)*
^{99m}Tc-sulfur colloid
^{99m}Tc-tetrofosmin
^{201}Tl-thallous chloride
^{133}Xe-xenon gas
^{90}Y-ibritumomab tiuxetan (CD20)†
^{90}Y-microspheres**

*Common chemical abbreviation.
†Antigen or receptor with which interaction occurs.
††Investigational new drug (IND) approval with the University of Michigan required.
§Red cells labeled with commercially available kit.
**Classified as a medical device for brachytherapy by the U.S. Food and Drug Administration.

TABLE 2
Radionuclides Available in the United States, 2005

Radioisotopes	Source	Radioisotopes	Source
$^{225}Ac/^{213}Bi$	Alp, DOE	^{103}Pd	MURR, Nor, TCI, CNL
^{26}Al	CNL	^{109}Pd	MURR
^{241}Am	Aur, CNL	^{147}Pm	Aur, CNL
^{243}Am	DOE	^{149}Pm	MURR
^{41}Ar	TX, OR	^{210}Po	CNL
^{73}As	DOE	^{191}Pt	MURR
^{198}Au	MURR, OSU, TX	^{195m}Pt	MURR, DOE-carrier free
^{133}Ba	DOE, INIS, Aur, CNL	^{240}Pu	DOE
^{7}Be	DOE, CNL	^{241}Pu	DOE
^{207}Bi	DOE, CNL	^{242}Pu	DOE
^{212}Bi	Alp	$^{224}Ra/^{212}Pb/^{212}Bi$	Alp
^{213}Bi	Alp	^{226}Ra	CNL
^{76}Br	WU	^{86}Rb	PE
^{77}Br	WU	^{186}Re	DOE, MURR, NOR
^{14}C	PE, Nor, CNL	^{188}Re	DOE, MURR
^{45}Ca	PE	^{105}Rh	MURR
^{109}Cd	DOE, PE, Aur, CNL	^{106}Ru	PE, CNL
^{139}Ce	CNL	^{33}S	CNL
^{141}Ce	PE	^{35}S	MURR, PE, CNL
^{252}Cf	DOE, Aur, CNL	^{122}Sb	MURR
^{36}Cl	PE	^{46}Sc	MURR, PE, TX
^{244}Cm	DOE, CNL	^{47}Sc	Alp
^{248}Cm	DOE	^{74}Se	CNL
^{57}Co	INIS, Nor, PE, Aur, CNL	^{75}Se	Aur, DOE, MURR
^{58}Co	CNL	^{76}Se	CNL
^{60}Co	DOE, INIS, PE, Nor, Aur, CNL	^{77}Se	CNL
^{51}Cr	MURR, PE, Nor	^{78}Se	CNL
^{137}Cs	INIS, Aur, CNL	^{80}Se	CNL
^{60}Cu	INIS, WU	^{82}Se	CNL
^{61}Cu	WU	^{32}Si	DOE
^{64}Cu	WU, Nor	^{153}Sm	MURR
^{67}Cu	Alp, DOE	^{113}Sn	PE
$^{166}Dy/^{166}Ho$	MURR	^{117m}Sn	DOE
^{55}Fe	Aur, DOE, PE, CNL	^{82}Sr	DOE, Nor, CNL
^{59}Fe	PE, CNL	^{85}Sr	DOE, PE, CNL
^{66}Ga	WU	^{89}Sr	DOE, CNL
^{67}Ga	BMS, Mal, Nor, CNL	^{90}Sr	DOE, Aur, CNL
^{68}Ga	CNL, TCI (from ^{68}Ge generator)	^{160}Tb	MURR
^{153}Gd	PE, CNL, Aur	^{94m}Tc	WU
^{68}Ge	DOE, INIS, PE, TCI, CNL	^{99}Tc	DOE, PE
^{3}H	PE, CNL	^{99m}Tc	Mal
^{166}Ho	MURR	^{123m}Te	MURR, DOE
^{123}I	Alp, Am, Mal, Nor	^{125m}Te	MURR
^{124}I	WU	^{129m}Te	MURR
^{125}I	CAL-D, Nor, PE, TX, TCI, CNL	^{228}Th	Aur, CNL
^{129}I	PE, CNL	^{229}Th	DOE
^{131}I	Drax, INIS, Nor, PE, TCI, Mal, CNL	^{230}Th	DOE
^{111}In	Alp, Am, Mal, Nor, PE, CNL	^{44}Ti	DOE, CNL
^{114}In	PE	^{201}Tl	Am, BMS, Mal, Nor
^{192}Ir	Aur, DOE, MURR, Nor, WSU, CNL	^{234}U	DOE
^{42}K	MURR	^{235}U	DOE
^{85}Kr	Aur	^{236}U	CNL
^{177}Lu	Aur, DOE, INIS, MURR, Nor, PE	^{238}U	DOE
^{54}Mn	PE, Aur, CNL	$^{188}W/^{188}Re$	DOE, CNL
^{99}Mo	Mal, Nor, TCI	^{133}Xe	Nor, Mal
^{22}Na	DOE, INIS, PE, Aur, CNL	^{86}Y	WU
^{24}Na	TX	^{88}Y	DOE, CNL
^{95}Nb	PE	^{90}Y	Aur, MURR, Nor, PE, CNL
^{63}Ni	Aur, DOE, PE	^{169}Yb	MURR, Aur
^{237}Np	CNL	^{65}Zn	DOE, MURR, PE, CNL
^{191}Os	MURR	^{68}Zn	CNL
^{32}P	MURR, Nor, PE, TCI, Mal, Aur, CNL	^{88}Zr	DOE
^{33}P	MURR, PE, CNL		

Alp = AlphaMed (Acton, MA); Am = Amersham Health (Princeton, NJ); Aur = Auriga Medical of AEA Technology QSA, Inc. (Burlington, MA); BMS = Bristol Myers Squibb (Princeton, NJ); CAL-D = University of California-Davis (Davis, CA); CNL = CNL Scientific Resources, Isotope Products Laboratories (Valencia, San Francisco, CA); DOE = U.S. Department of Energy (Washington, DC); Drax = Draximage Inc. (Quebec, Canada); INIS = International Isotopes, Inc. (Idaho Falls, ID); Mal = Mallinckrodt Corporation (St. Louis, MO); MURR = University of Missouri Research Reactor (Columbia, MO); Nor = MDS Nordion Corporation (Ottawa, ON, Canada); OR = Oregon State University (Corvallis, OR); OSU = Ohio State University (Columbus, OH); PE = PerkinElmer Life and Analytical Sciences (Boston, MA); TCI = TCI Medical, Inc. (Albuquerque, NM); TX = Texas A&M University (College Station, TX); WSU = Washington State University (Pullman, WA); WU = Washington University (St. Louis, MO).

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and Michael J. Welch, PhD, a professor of radiology and chemistry and director of the department of radiology's research division at Washington University School of Medicine (St. Louis, MO).

We told the representatives from OMB and the Office of Science and Technology—and I repeated the concerns to Raymond L. Orbach, PhD, director of DOE's Office of Science—that the future of effective therapies and cutting-edge basic research in molecular imaging and nuclear medicine depends on DOE funding. SNM recognizes that there are many competing priorities in the FY 2006 federal budget as well as serious fiscal challenges that the nation faces. However, without funding for molecular/nuclear imaging programs, nuclear medicine research will be severely curtailed, and millions of our patients with cancer, brain diseases, and diseases of the heart could be adversely affected.

Research and development carried out with DOE funding have made pioneering contributions that have formed the basis of molecular imaging/nuclear medicine as practiced today. These achievements have had a major impact on the growth of molecular imaging/nuclear medicine and on the lead our nation enjoys in the field. The list of accomplishments brought about by DOE funding is long and includes the development of the Anger gamma camera, a primary tool; the ^{99m}Mo/^{99m} Tc generator, the workhorse; PET, the driving force of modern molecular imaging/nuclear medicine; ^{18}F-FDG, which promotes metabolic imaging; and many other key radiopharmaceuticals of diagnostic and therapeutic importance that are either in routine practice or promise to keep molecular imaging/nuclear medicine on the cutting-edge of ever-evolving modern medicine.

However, only Congress can reverse the budget cuts. We simply cannot afford to sit back and watch this situation become a reality. While we all cannot personally provide our perspectives on Capitol Hill, we can let our lawmakers know that these funding cuts are unacceptable. Since SNM issued its call to action, nearly 2,700 messages (both e-mail and print) have been sent to Capitol Hill lawmakers denouncing the proposed budget cuts. Clearly, the impact on Congressional lawmakers would be exponentially greater if *all* of our 16,000 members and *Journal of Nuclear Medicine* subscribers wrote to object to the suggested cuts. SNM has made this process very easy, providing an online legislative action center that supplies recommended e-mail text. The online action center also automatically determines your representatives (based on your zip code) and provides their e-mail addresses.

On behalf of the society, I thank those who have already taken the time to send letters, and I appeal to others to take action and let your national representatives know you support molecular imaging/nuclear medicine programs. Visit the SNM Web site at www.snm.org and click on Government Relations for the link to the online legislative action center. The window of opportunity still exists. Please do not procrastinate, as procrastination is the grave in which opportunity can get buried. *SNM and the molecular imaging/nuclear medicine profession need your help!*

Mathew L. Thakur, PhD
President, SNM

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DOE. It is reassuring to note the multiple suppliers of ^{57}Co, of which there was a recent shortage. Several companies are now making available ^{68}Ge, ^{177}Lu, and other radionuclides appearing more frequently in our nuclear medicine literature.

These lists were reviewed by the following individuals who gave generously of their time: Robert W. Atcher, PhD; Joseph C. Hung, PhD; Henry H. Kramer, PhD; and all the members of the Council on Radionuclides and Radiopharmaceuticals, Inc., to whom he sent these lists; John Pantaleo of the DOE; James A. Ponto, MS; and Wynn A. Volkert, PhD. These lists are published here with the understanding that the organizations have said that they can or will provide these radionuclides in 2005. It is almost certain that some of these radionuclides cannot be provided without some period of delay for production. If any producers or radionuclides have been omitted, we will publish addenda as needed.

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Member and Past-Chair
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