Trends and Utilization of Nuclear Medicine in the United States: 1972–1982

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In the decade 1972–1982, in vivo nuclear medicine procedures in the United States increased from 3.3 million to about 7.5 million per annum. This growth has been the result of a markedly increased frequency in some types of examinations; particularly bone, liver, lung, and cardiovascular imaging. The only type of imaging in which a decrease in frequency has been observed has been in radionuclide brain imaging. Examination of these trends illustrates the difficulty in forecasting, even over time periods as short as 5 years. Competing tests have largely replaced radionuclide imaging in some areas; although in other areas, such as cardiac nuclear medicine, competing technologies appear to have been additive in terms of the frequency of examinations. Comparison with recent data from other countries indicates that the frequency of nuclear medicine procedures in the United States is probably the highest in the world.

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Nuclear medicine has always been hampered by poor resolution compared with radiographic imaging procedures. Even current nuclear medicine images cannot compare with the resolution of the earliest radiographs obtained by Roentgen. In spite of the relatively poor spatial resolution, the use of radioactive tracers to assess and quantitate regional blood flow, organ function, and other in vivo biological processes has provided nuclear medicine with a rather unique place in medical diagnosis and practice.

Even with the advent and rapid expansion of both computerized tomography and gray scale ultrasound, there has been a marked growth in the frequency of nuclear medicine procedures performed. There has been only one brief report (*1*) of the number of examinations in the United States in the last 6 years, and that report dealt only with frequencies for the year 1980. It is the purpose of this paper to assess the trends in the various procedures, compare the frequency of specific procedures with competing modalities, and finally, to establish a base of information which can be utilized for other purposes, such as estimating the absorbed dose to the population from the practice of nuclear medicine.

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METHOD

Data on the frequency and total number of nuclear medicine procedures has been derived from several different sources. The 1972 data was collected by J. Lloyd Johnson Associates in cooperation with the American College of Radiology and was presented in a survey on regionalization in nuclear medicine (*2*). Data for the years 1973 and 1975 was obtained in a similar fashion and published in the American College of Radiology Manpower Survey (*3*).

In 1975, the Bureau of Radiological Health (BRH), USFDA, initiated a pilot project to survey nuclear medicine examinations in six hospitals. This data was reported through the Medically Oriented Data System (MODS). The project was later expanded to include 26 stratified hospitals and data from these hospitals was collected from August, 1977 through July, 1978.

Comprehensive data on 1980 diagnostic imaging procedure volume was collected (by mail questionnaire) by J. Lloyd Johnson Associates using a stratified random sample of general hospitals and selected office practices in the United States (*1*). The sample included 6,109 hospitals and is estimated to reflect 90% of the total diagnostic imaging examinations.

In 1980 and 1981, the Bureau of Radiological Health (now the Center for Medical Devices and Radiological Health, CDRH) conducted a hospital-based survey which was called the Radiation Experience Data (RED 1) study. The RED 1 study examined the computer billing records of 81 hospitals. Additional information concerning age and sex of the patients was obtained from radiology department log books. RED 1 data is concerned with imaging and includes not only x-ray examinations, but also nuclear medicine, ultrasound, and computerized tomography. The relative standard error for the total number of nuclear medicine procedures was 2.6 percent. To date, only the data for 1980 is available. Since the RED 1 study turned out to be very expensive, it was only conducted for the years 1980 and 1981.

Data from 1981 and 1982 is available from another Center for Medical Devices and Radiological Health (CDRH) study. In 1981, the CDRH contracted with a commercial source to obtain and utilize trend analysis of radiographic and nuclear medicine procedures. The data is more limited than RED 1 but still contains radiation experience data and this study has been termed RED 2. The data was collected by mail survey and includes numbers of procedures performed. This information is derived from summaries of hospital radiology departments. There are 500 hospitals in the survey group which are not randomized. The group, however, is a fairly wide representation of hospitals throughout the country. The number of various procedures is provided for the first and third quarter of each year and can be extrapolated to the entire U.S. hospital population. There are fairly detailed categories of routine radiological examinations, special procedures, computerized tomography, ultrasound, and nuclear medicine examinations. This survey also includes the type and quantity of contrast material used. The RED 2 data is somewhat different from RED 1 in that the number of hospitals was increased from 100 to 500, but the hospitals are not randomized and there is no sex or age information obtained on the patients having the examinations. Much of this CDRH data (MODS, RED 1, RED 2) is available to the public even though it has not been published.

Another study was done in 1981–1982 by Parker et al. (*4*). This latter study was a randomized sample of

TABLE 1
Estimated Number of Diagnostic Radionuclide In Vivo Examinations in the United States (X 1,000)

	Year								
	1972	1973	1975	1978	1980	1980	1981	1982	1982
	Source								
Item	ACR	ACR	ACR	MODS	Johnson	RED 1	RED 2	RED 2	Parker
Brain	1,250	1,510	2,120	1,546	870	1,176	1,038	812	—
Hepatobiliary	26	—	—	—	—	—	109	179	—
Liver	455	535	676	1,302	1,180	1,399	1,445	1,424	—
Bone	81	125	220	1,160	1,270	1,307	1,613	1,811	—
Respiratory	332	417	597	1,053	830	898	1,095	1,191	—
Thyroid	356	460	627	699	650	506	664	677	533
Urinary	108	122	154	205	200	164	402	236	—
Tumor	10	14	22	166	130	—	125	121	—
Cardiovascular	25	33	49	160	580	558	708	950	—
Other	405	294	338	115	110	368	—	—	—
Total	3,339	3,510	4,803	6,411	5,830	6,374	6,999	7,405	7,690
	(16)*	(17)	(22)	(29)	(26)	(28)	(31)	(32)	(33)

* Numbers in parenthesis indicate number of examinations/1,000 population.

TABLE 2
Estimates of United States Hospital Head X-Ray Examinations (× 1,000)

Examination	Year 1964	1970	1972	1973	1978	1980	1982
Source	XES 64	XES 70	ACR	ACR	MODS	JOHNSON	RED 2
Head CT	—	—	0	<10	—	2,300	2,481
Skull	2,523	3,616	—	—	—	5,600	5,700
Pneumoencephalogram	—	48	—	—	—	2	—
Arteriogram	121	—	—	—	—	315	1,164
RN brain scan	—	—	1,250	1,510	1,546	867	812
RN cisternogram	—	—	12	—	—	16	13

10% of the U.S. hospitals performing nuclear medicine procedures. The survey was directed specifically at thyroid examinations, but also gave data concerning the total number of in vivo nuclear medicine examinations.

All of the above listed studies have been based on hospital data only. This was felt to be adequate since less than 1% of all nuclear medicine procedures are performed outside of hospitals. Johnson et al. (*1*) indicate that only 30,000 of 5,830,000 in vivo nuclear medicine examinations were performed in private practice settings in 1980.

Data on frequency of radiographic examinations used for comparison was obtained from some of the data sources listed above. Additional radiographic data was available from 1964 and 1970 population x-ray exposure surveys (XES) conducted by the U.S. Bureau of Radiological Health (*5,6*).

RESULTS

The number and type of procedures performed during various years in the decade 1972–1982 are shown in Table 1. By 1982 there were fewer radionuclide brain imaging examinations than in 1972, undoubtedly due to replacement by computerized tomography. Liver imaging increased by 300% in this decade and bone imaging increased by over 1,000%. The growth in cardiovascular procedures has been even more spectacular. Other procedures such as renal, lung, and tumor imaging have experienced moderate growth. Data on the frequency of thyroid examinations is complicated by the fact that uptakes and thyroid imaging are often reported separately even though they may be performed concurrently. In Table 1, thyroid imaging and uptakes performed together are usually listed as one examination. On the other hand, a lung perfusion and ventilation imaging study is listed as two respiratory examinations. The reason for this is probably that a different radiopharmaceutical is utilized for each part of the lung study. The frequency of all diagnostic nuclear medicine procedures has increased over the decade from 16 per thousand population in 1972 to 32 per thousand population in 1982.

The role of competing or complementary technology either in terms of radiology or ultrasound is shown in Tables 2–6. Table 2 indicates that head computed tomography (CT) has substantially reduced the frequency of both pneumoencephalograms and radionuclide brain imaging; however, the frequency of both skull radiographs and cerebral angiography has continued to increase. Table 3 indicates that radionuclide thyroid examinations have been stable in number since 1978. However, since the U.S. population was increasing during this period, there was a relative decrease in frequency. Thyroid ultrasound has had no substantial effect on the frequency of radionuclide thyroid studies.

Cardiac procedures have undergone rapid expansion

TABLE 3
Thyroid Imaging and Uptake Examinations in United States Hospitals (× 1,000)

	Year 1966	1975	1978	1980	1981	1982
Item	UNSCEAR 1982	ACR	MODS	Johnson	RED 2	RED 2
Thyroid uptakes and scans	454	627	699	650	664	677
Thyroid ultrasound	—	—	—	—	69	66

TABLE 4
Estimates of Hospital Cardiac Imaging Procedures (X 1,000)

	Year				
	1972	1973	1980	1981	1982
	Source				
Examination	ACR	Johnson	Johnson	RED 2	RED 2
Angiocardiography and coronary angiography	—	200	504	424	409
Echocardiography	0	—	1,400	—	—
Radionuclide blood pool	11	25	—	320	498
Radionuclide infarct scan	2	—	580	148	140
Radionuclide scan perfusion/ischemia thallium	0	—	—	228	302

(Table 4) in all examination types. Between 1980 and 1982, contrast angiographic studies may have decreased slightly but whether this will continue as a trend is uncertain. Overall, most of these cardiac examinations appear to have been additive in terms of numbers. The only area in which substitution may have occurred is in replacement of some radionuclide infarct scans by thallium myocardial or blood-pool scans.

Biliary imaging procedures are shown in Table 5. The number of oral cholecystograms has declined markedly between 1980 and 1982. This is probably the result of replacement by both ultrasound and hepatobiliary scintigraphy. Table 6 lists hepatic imaging procedures. The number of radiocolloid liver imaging studies appears to have peaked or even decreased. The reason for this is difficult to determine. Certainly both ultrasound and CT have had an impact. It is virtually impossible to assess the impact of body CT since the organ of interest for which abdominal CT scans are performed is not usually available in survey data.

DISCUSSION

In spite of the advent and rapid expansion of both gray scale ultrasound and computerized tomography (CT) in the decade 1972–1982, the frequency of in vivo diagnostic nuclear medicine examinations doubled. There has been numerical addition of some of these techniques in some organ areas while in other areas there has been clear replacement. The major replacement, of course, has occurred in the area of brain imaging. The information supplied by a contrast-enhanced CT scan is not only anatomic but also to some extent physiologic.

The rapid expansion of radionuclide gated blood-pool studies and myocardial perfusion studies have occurred in spite of a major boom in echocardiography. Presumably, the information obtained from each type of study is additive or at least complementary, rather than being identical. The role of radiographic digital contrast imaging in this area remains to be determined. The possible effect of "planned duplication" to compare an emerging technology with an existing one has been

TABLE 5
Trends in United States Hospital Biliary Imaging Procedures (X 1,000)

	Year				
	1964	1970	1972	1980	1982
	Source				
Examination	XES 64	XES 70	ACR	Johnson	RED 2
Oral cholangiogram	1,982	2,110	—	2,900	2,468
Intravenous cholangiogram	87	179	—	130	67
Percutaneous cholangiogram	—	—	—	32	27
Biliary ultrasound	0	0	—	—	1,356
Radionuclide hepatobiliary	—	—	26	—	179
Operative cholangiogram	—	—	—	—	271
Endoscopic retrograde cholangiogram	—	—	—	38	44
T-tube cholangiogram	—	—	—	—	104

TABLE 6
Hepatic Imaging Procedures in United States Hospitals (X 1,000)

	Year					
	1972	1974	1978	1979	1981	1982
	Source					
Examination	ACR	ACR	MODS	Johnson	RED 2	RED 2
Radionuclide liver scan	455	535	1,302	1,368	1,445	1,424
Hepatic ultrasound	—	—	—	—	314	676
Hepatic CT*	—	—	—	—	13	14

* A large number of abdominal CT examinations are unspecified.

considered. The current data base does not allow separation of the procedures by physicians intent or purpose at the time of ordering.

There are lessons to be learned from the evaluation of these trend data. The first is that the prediction of the future of nuclear medicine is extremely difficult. The trends from 1972 to 1975 could have been used to estimate the total number and types of examinations in 1980. If this were done, the total number of examinations would have been extremely close to that which actually occurred. However, the numbers involved for each of the types of examinations used to derive the total would have been largely wrong. For example, in the absence of CT scanning one would have predicted that radionuclide brain imaging would have continued to grow, and in addition, there was little reason in 1975 to expect the rapid growth of cardiac procedures.

The second lesson is that the ability of nuclear medicine to evaluate regional physiology and metabolism has been and will continue to be its strength. It remains to be seen whether magnetic resonance imaging will be able to supply such information. Because of the time required to compile data, this paper only includes data through 1982. Since that time, there have been significant changes in reimbursement mechanisms, which undoubtedly will affect the numbers and type of procedures being performed. We feel that speculation regarding the nature and magnitude of the changes is premature and suggest that additional data collection through 1985 is essential.

In summary, the frequency of nuclear medicine procedures in the U.S. at 33 per 1,000 population is generally higher than that of other developed countries. The frequency of examinations (per 1,000 population) has been reported as follows: Sweden 8.4 in 1971 and 13.6 in 1976; Denmark 3.8 in 1973 and 14 in 1978, Austria 17.5 in 1977 (*7*). In the last decade, while nuclear medicine procedures have changed markedly in type, the overall frequency of examinations has doubled.

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