2 .

Number and Distribution of CT Scanners

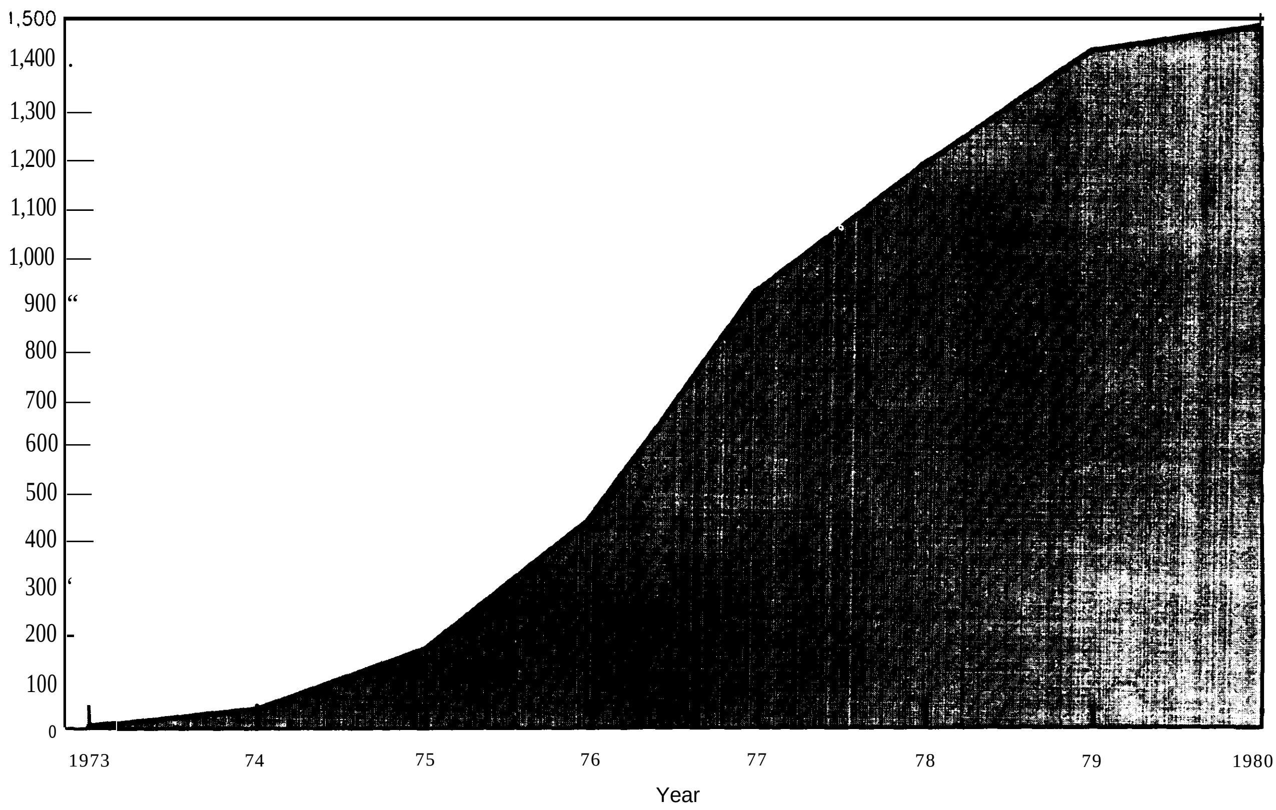
2.

Number and Distribution of CT Scanners

By May 1, 1980, there were 1,471 operational scanners in the United States. This number of operational scanners has been rapidly attained (see figure 1). ' At the end of 1974, only 45 scanners were in operation. Two years later, at the end of 1976, the number of operational scanners had increased to 475. Diffusion was even more rapid in 1977, when about 40 scanners were installed per month. During 1978, however, the rate of installation of scanners fell by nearly half, In 1979 and the first 4 months of 1980, the rate fell a little more, to about 17 scanners per month.

'Based on data collected through April **1980.**

Figure 1.—Cumulative Number of CT Scanners Installed (1973-80)



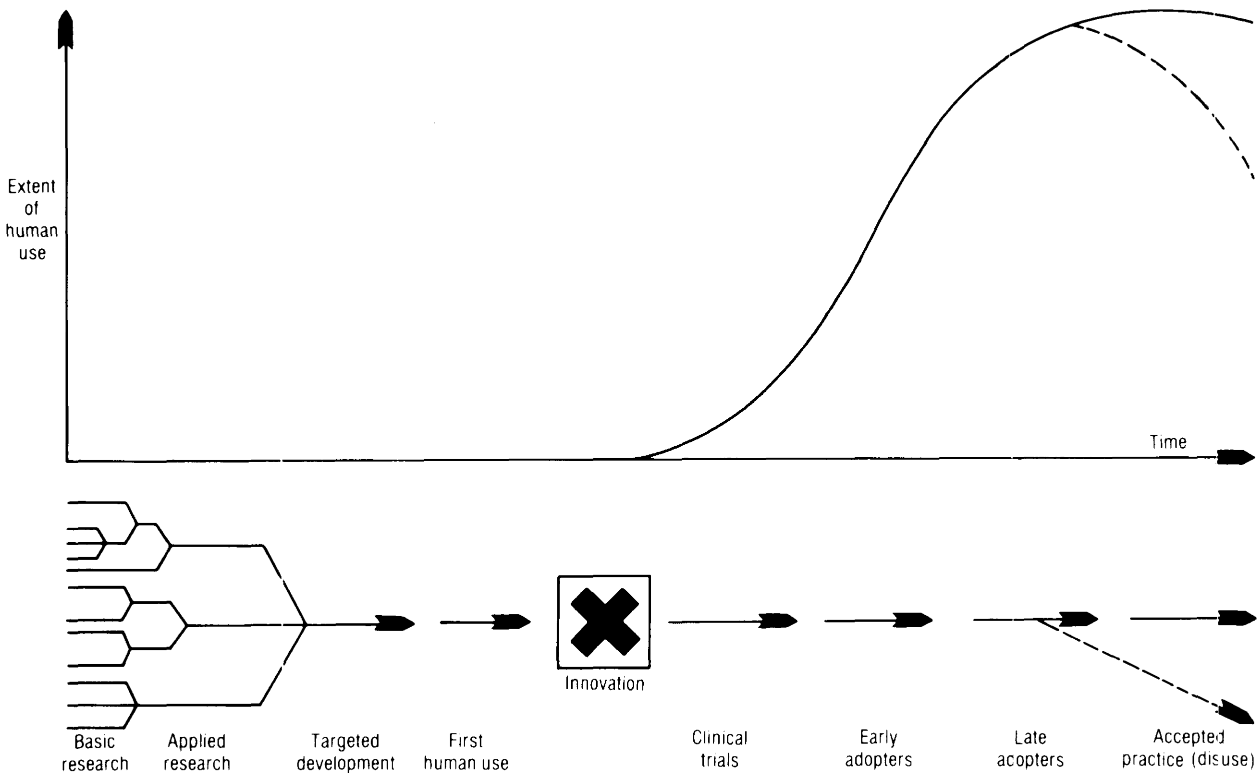
SOURCE Off Ice of Technology Assessment

DIFFUSION OF' MEDICAL TECHNOLOGY– SOME GENERAL CONSIDERATIONS

The process by which a technology enters and becomes part of the health care system is known as diffusion. The diffusion of a technology follows the stage of R&D and may or may not occur following careful clinical trials to demonstrate efficacy and safety. Descriptive research has shown that the diffusion process for any technology usually follows an S-shaped or sigmoid curve, relating the percentage of potential adopters to actual adopters (see figure 2). Generally, there is an early phase of diffusion that is somewhat slower. This has been interpreted as indicating caution on the part of users (145), although it could also indicate problems of communication of information about the innovation (126). As experience indicates that the technology does indeed have some benefit, acceptance increases. Finally, when most potential adopters have accepted the innovation, diffusion slows and the curve flattens. Although most of the work demonstrating the S-shaped diffusion curve is outside the health care area, this curve has been documented for such medical technologies as intensive care units (1.46), cardiac pacemakers (126), respiratory therapy (146), diagnostic radioisotope facilities (1.46), and electroencephalographs (146).

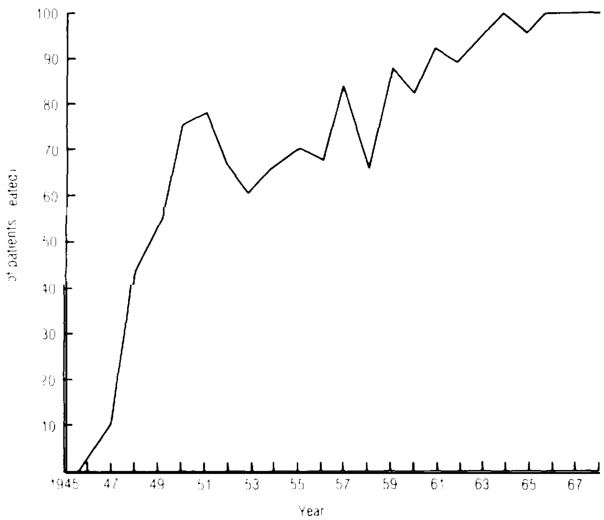
The diffusion of medical technologies does not always follow the sigmoid curve. One major departure from this model occurs when diffusion reaches a high rate almost immediately

Figure 2.—A Scheme for Development and Diffusion of Medical Technologies



SOURCE Off Ice of Techology Assessment, U S Congress, *Development of Medical Technology Opportunities for Assessment* (Washington, D C Government Printing Off Ice, August 1976) after the technology becomes available (see figure 3). This pattern has been referred to as the "desperation-reaction model" (182). A first phase of rapid diffusion seems to occur because of the provider's sense of responsibility to help the patient and their mutual desperation. Later, results of clinical tests and experience begin to influence the physician's behavior. If results of tests are positive, diffusion may continue rapidly. If the evidence is not clear cut, there may be caution and slow diffusion. If the evidence seems negative, use of the technology gradually declines.

Figure 3.— Diffusion of Chemotherapy for Leukemia



SOURCE K Warner, "A 'Desperation-React!on' Model of Medical Diffusion," *Health Service* Research 10369, 1975. Redrawn by the Off Ice of Technology Assessment

Whatever its initial pattern of diffusion, a technology may eventually be partially or completely abandoned. The rate of tonsillectomy (surgical removal of the tonsils), for example, is presently declining (119). Such a decrease in use can result from additional knowledge or the introduction of a more effective technology. The introduction of polio vaccine, for example, almost overnight entirely supplanted the costly halfway technology of rehabilitation centers (176).

Little work has been done on the diffusion of specific medical technologies, but some comparisons can be made. Intensive care is an expensive technology that had its most rapid spread in U.S. hospitals from 1960 to 1968. The most rapid diffusion rate was slightly over 200 per year, or less than 20 per month (146). Another technology, nuclear medicine, spread at the rate of almost 200 facilities per year during the period 1969 to 1972 (141), As noted above, the diffusion of CT scanners was considerably more rapid than the diffusion of either of these two technologies. The more rapid diffusion of CT scanners could be due in part to the change in reimbursement policies since the 1960's.

Technologies have been observed to diffuse most rapidly among large hospitals **(146).** Early diffusion to hospitals affiliated with medical schools was observed for intensive care (146) and nuclear medicine (141). Cromwell, et al. (39), however, found that when size and long-term debt were held constant, medical school affiliation had little effect *on* equipment expenditures. These investigators also showed that technologies diffuse more rapidly as the percentage of hospital resources from third parties increases. As seen below, except for its rapidity, the diffusion of CT scanners generally follows the pattern predicted by previous research.

The sections that follow give detailed information on the diffusion and present distribution of CT scanners.

DISTRIBUTION OF OPERATIONAL SCANNERS[2]

Geographic Distribution

Table 2 summarizes information on the location of scanners by State. All States have at least one scanner. There are no scanners in American Samoa, Guam, the Trust Territory of the Mariana Islands, or the Virgin Islands. The national average is now about 6.7 scanners per million population. Washington, D. C., has the highest ratio, with 16.7 scanners per million population. States with high scanner-to-population ratios include Nevada (12.8), Florida (10.9), California (10.5), Missouri (9.4), North Dakota (9.1), Arizona (9.0), Nebraska (8.3), and New Mexico (8.0). States with the lowest scanner-to-population ratios include South Carolina (2.4), Rhode Island (3.3), Idaho (3.3), Delaware (3.4), Michigan (3.6), New Jersey (3,7), Kentucky (3.7), and Montana (3.8). Puerto Rico has only about 1.6 scanners per million population. Table 3 shows that a ranking of States according to scanner-per-population ratios changed little with the addition of new scanners between February 1979 and May 1980.

[2]Numbers in this paper may differ from those in the **1978** OTA report on CT scanners because they include additional scanners identified, replacements, and so on.

Table 2.— Distribution of CT Scanners by Region and State (May 1980)

Region and State	Number of CT scanners		Number of CT scanners per million population[a]		
	Hospital	Office	Hospital	Office	Total
New England	48	9			
Maine	5	0	4.6	—	4.6
New Hampshire	3	1	3.4	1.3	4.7
Vermont	1	1	2.3	2.3	4.6
Massachusetts	25	5	4.3	0.9	5.2
Rhode Island	2	1	2.2	1.1	3.3
Connecticut	12	1	3.9	0.3	4.2
Middle Atlantic	147	56			
New York	61	42	3.5	2.4	5.9
New Jersey	20[b]	7	2.7	1.0	3.7
Pennsylvania	66[b]	7	5.6	0.6	6.2
East North Central	190	41			
Ohio	50	12	4.7	1.1	5.8
Indiana	24	6	4.4	1.1	5.5
Illinois	69[c]	11	6.1	1.0	7.1
Michigan	27	6	2.9	0.7	3.6
Wisconsin	20	6	4.2	1.3	5.5
West North Central	107	15			
Minnesota	17	6	4.2	1.5	5.7
Iowa	13	4	4.5	1.4	5.9
Missouri	44	2	9.0	0.4	9.4
North Dakota	5	1	7.6	1.5	9.1
South Dakota	3	0	4.4	—	4.4
Nebraska	11	2	7.0	1.3	8.3
Kansas	14	0	5.9	—	5.9
South Atlantic	205	51			
Delaware	1	1	1.7	1.7	3.4
Maryland	21[d]	6	5.1	1.4	6.5
District of Columbia	10	1	15.2	1.5	16.7
Virginia	27	4	5.2	0.8	6.0
West Virginia	9	1	4.8	0.5	5.3
North Carolina	28	4	5.0	0.7	5.7
South Carolina	7	0	2.4	—	2.4
Georgia	32	7	6.2	1.4	7.6
Florida	70[c]	27	7.9	3.0	10.9

Table 2.—Distribution of CT Scanners by Region and State (May 1980)–continued

Region and State	Number of CT scanners		Number of CT scanners per million population[a]		
	Hospital	Office	Hospital	Office	Total
East South Central ...,	67	6			
Kentucky, ..., ..., ..., ...,	11	2	3.1	0.6	3.7
Tennessee. ..., ..., ...	24	3	5.5	0.7	6.2
Alabama ., ..., ..., ...,	22	0	5.8	—	5.8
Mississippi ., ., ..., ..., ..., . . .	10	1	4.1	—	4.1
West South Central	126	1			
Arkansas	9	1	4.1	0.5	4.6
Louisiana	25[b]	3	6.2	0.7	6.9
Oklahoma	15	0	5.2	·	5.2
Texas	77	25	5.8	1.9	7,7
Mountain	62	14			
Montana	3	0	3.8	—	3.8
Idaho	3	0	3.3	—	3.3
Wyoming. . ., ...,	2	0	4,4	—	4,4
Colorado	17	3	6.1	1.1	7,2
New Mexico	5	5	4.0	4.0	8.0
Arizona	18[c]	4	7.3	1.6	9.0
Utah.	6	1	4.4	0.7	5.1
Nevada.	8	1	11.4	1,4	12.8
Pacific. . . . ., ...,	239	54			
Washington. . . . .,	19	11	4.8	2.8	7.6
Oregon.	16	0	6.3	—	6.3
California. . . ., ...	196[e]	43	8.6	1,9	10.5
Alaska . . . ., ..., .	3	0	7.4	—	7.4
Hawaii ., ..., ..., ..., ...	5	0	5.5	—	5.5
Puerto Rico.	2	3	0.6	1.0	1.6
Subtotal	1',193	278	5.4	1.3	6.7
Total scanners in the United States ..., ...	1,471			6.7	

[a] Population data were obtained from the U S Bureau of the Census
[b] Including 1 mobile scanner
[c] Including 2 mobile scanners
[d] Including 3 scanners at the National Institutes of Health. If they are removed from the totals, Maryland has 58 scanners per million population
[e] Including 8 mobile scanners

The ratio of scanners per million population is often used as a standard by which to compare scanner availability in the United States to scanner availability in other countries. Table 4 gives the number of CT scanners in the United States and in a number of other industrialized countries early in 1979. It seems apparent from these data, and from other sources, that the United States at present has the greatest number of CT scanners of any country in the world. This information is not easy to interpret, however, because the appropriate number of scanners is not known. One also needs to consider that the United States has, in addition to scanners, the greatest amount of other diagnostic technologies such as conventional X-ray **(120)** and a large number of surgeons per capita in comparison to such countries as Canada and the United Kingdom (28,178).

Within the United States, the ratio of scanners per million population is often used as an indicator of relative geographic maldistribution from State to State, as the discussion above illustrates. The ratio is inadequate as an indicator of relative access, however, because it does not incorporate the geographic dimension of access. The ranking of States by number of square miles is shown in the last column of table 3. It is striking that the 10 States with the highest scanner-to-population ratios are all relatively large States characterized by relatively low population densities. Several of these States are further characterized as mostly rural, so their population may be expected to be dispersed over the State.

The point to be made is that both population and geography are essential factors to consider

Table 3.—Ranking of States by CT Scanners per Million Population as of February 1979 and May 1980

States (ranked by May 1980 ratio of scanners/ million population)	May 1980 ratio of scanners/million population	February 1979 ratio of scanners/million population	State ranking based on 1979 ratio of scanners/ million population	State ranking based on size in square miles
1. Nevada	12.8	12.8	1	7
2. Florida	10.9	10.3	2	22
3. California	10.5	9.8	3	3
4. Missouri	9.4	8.3	4	19
5. North Dakota	9.1	7.7	7	17
6. Arizona	9.0	7.8	6	6
7. Nebraska	8.3	8.3	5	15
8. New Mexico	8.0	4.2	37	5
9. Texas	7.7	6.3	12	2
10. Georgia	7.6	7.5	8	21
11. South Carolina	7.6	2.1	50	40
12. Washington	7.6	6.3	13	20
13. Alaska	7.4	7.4	9	1
14. Colorado	7.2	7.2	10	8
15. Illinois	7.1	6.0	14	24
16. Louisiana	6.9	5.6	18	31
17. Maryland	6.5	6.3	11	41
18. Oregon	6.3	5.2	20	10
19. Pennsylvania	6.2	4.5	30	33
20. Tennessee	6.2	6.0	16	34
21. Virginia	6.2	4.5	31	36
22. Iowa	5.9	4.2	36	25
23. Kansas	5.9	4.7	26	14
24. New York	5.9	4.8	25	30
25. Alabama	5.8	4.9	23	29
26. Ohio	5.8	4.4	32	35
27. Minnesota	5.7	6.0	15	12
28. North Carolina	5.7	4.9	24	28
29. Hawaii	5.5	4.5	29	47
30. Indiana	5.5	5.3	19	38
31. Wisconsin	5.5	5.2	21	36
32. Massachusetts	5.4	3.6	41	45
33. West Virginia	5.3	4.3	34	42
34. Oklahoma	5.2	4.6	28	18
35. Utah	5.1	5.1	22	11
36. New Hampshire	4.7	4.7	27	44
37. Arkansas	4.6	4.2	35	27
38. Maine	4.6	3.6	40	39
39. Vermont	4.6	4.2	38	43
40. South Dakota	4.4	4.4	33	16
41. Wyoming	4.4	2.5	48	9
42. Connecticut	4.2	3.6	39	48
43. Mississippi	4.1	3.3	44	32
44. Kentucky	3.7	3.2	45	37
45. New Jersey	3.7	2.6	47	46
46. Michigan	3.6	3.4	43	23
47. Delaware	3.4	3.4	42	49
48. Idaho	3.3	5.8	17	13
49. Rhode Island	3.3	2.2	49	50
50. Montana	3.0	3.0	46	4

SOURCE. Office of Technology Assessment.

in determining access, This is of particular importance when making comparisons of access between States or countries. An intuitive appreciation of the relationship between population and geography is illustrated by comparing the availability of CT scanners in the largest State, Alaska, and the smallest, Rhode Island. 130th States have three scanners, but Alaska has 7.4 scanners per million population while Rhode Island has only 2.2. Few would infer from this in-

Table 4.— Distribution of Installed CT Scanners in 10 Countries (1978 and 1979)

Country[a]	March 1978 Number of scanners Head	Body	Total	Scanners per million population	1979 Number of scanners Head	Body	Total	Scanners per million population
United States. . . .	337	668	1,005	4.6	400	854	1,254	5.7 (Feb.)
Japan ., ...	180	112	292	2.6	304	212	516	4.6 (Apr.)
West Germany.	51	42	93	1.5	u	u	160	2.6 (July)
Australia.	u	u	u	u	7	21	28	1.9 (Jan.)
Canada.	u	u	u	u	9	29	38	1.7 (May)
Sweden.	8	5	13	1.6	8	6	14	1.7 (Feb.)
Netherlands[b].	u	u	u	u	u	u	20	1.4 (Jan.)
United Kingdom .,	36	16	52	0.9	39	18	57	1.0 (Jan.)
France[c].	10	2	12	0.2	20	10	30	0.6 (Jan.)
Iceland	0	0	0	0.0	0	0	0	0.0 (Jan.)

Key to symbols U = Unknown
aRanked by scanners per million population in 1979
bThe Netherlands has planned to Install 30 head scanners and 8 body scanners
cIn France an additional 21 scanners were authorized in July 1979

SOURCE Reprinted from reference 128 Data sources can be found there

formation, however, that Alaskans have better access to scanners (according to geographic availability) than Rhode Islanders. On the other hand, the population of Rhode Island is almost twice that of Alaska. Consequently, its greater population density implies that access may be greater in the geographic sense, but less in terms of the greater population served.

OTA suggests consideration, therefore, of an alternative index of scanner availability that would incorporate the geographic dimension of access. The index is based on the index used to compare physician availability for any designated unit of analysis (124). The unit of analysis that would be most appropriate in this case would be individual health services areas.[3] First, a ratio of the number of scanners in a health service area to the number of scanners in the entire United States would be computed. Next, a ratio of the population density (persons per square mile) of the health services area to the population density of the United States would be determined. The availability index of the geographic unit of analysis would be the weighted average of the ratio between the first ratio and the second. This index would have the advantage of incorporating the relative impacts of geographic effects and population effects on access. The calculation of such an index would not give a clear indication of what appropriate access should be, since the only point of reference would be the national average. Although this index would not be the ideal indicator, given the data currently available, it would be an improved indicator to use in discussions of comparative accessibility.

In terms of health service areas, the distribution of scanners has improved. In 1979, there were 16 health service areas with no CT scanners, but now there are only 3. Table 5 shows the number and type of CT scanner (head or body) by health service area of May 1980. Although health service areas are smaller units than States, and therefore give a better sense of geographic distribution, some encompass the entire State. However, the ratio of scanners to population still varies greatly from one health service area to another.

Institutional Distribution

In May 1980, 18.9 percent of the 1,471 operational scanners were in private offices and clinics: This is *very close* to the figure of 19 percent observed in the May 1977 data presented in the original OTA CT report (129). Table 2 shows the number of scanners in noninstitutional settings by State. More importantly, table 2 also shows the ratio of private office scanners to population. States with high ratios include New Mexico, with 4.0 scanners per million per-

[3]Health service areas are the geopolitical areas served by corresponding health systems agencies (HSAS).

Table 5.— Number of CT Head and Body Scanners by Health Service Areas (May 1980)

State	Health service area (by number) 1	2	3	4	5	6	7	8	9	10	11	12	13-	14	Total
Alabama	2B	1B	6B 2H	2B	4B 1H	2B 2H	• —								5H
Alaska		2B	1B												3B —
Arizona	9B 3H	3B 3H	1H	* —	2B 1H										14B 8H
Arkansas	3B	1H	3B 1H	1B 1H											7B 3H
California	4B 3H	6B 4H	3B 2H	17B 5H	14B 7H	3B 2H	6B 7H	5B 2H	4B 5H	3B 3H	47B 40H	9B 2H	12B 5H	12B 7H	145B 94H
Colorado	11B 4H	3B 1H	1H												14B 6H
Connecticut	3B 1H	3B	1B	1B 1H	3B										11B 2H
Delaware	1B 1H														1B 1H
District of Columbia	8B 3H														8B 3H
Florida	3B 3H	4B 1H	5B 2H	14B 7H	5B 2H	9B 3H	7B 2H	7B 3H	14B 6H						68B 29H
Georgia	* 1H	2B 1H	13B 4H	4B* 1H	4B* 2H	3B 1H	2B 1H								28B 11H
Hawaii	3B 2H														3B 2H
Idaho	2B 1H														2B 1H
Illinois	3B 1H	2B 1H	3B 1H	2B 3H	2B	17B 8H	15B 8H	5B 2H	1B 1H	1B*	3B* 1H				54B 26H
Indiana	7B 3H	10B 3H	6B 1H												23B 7H
Iowa	11B 3H	2B*	*												13B 4H
Kansas	1B	1B 2H	3B 1H	5B* 1H											10B 4H
Kentucky	5B 2H	6B	* —												11B 2H
Louisiana	11B 4H	5B 1H	6B 1H												22B 6H
Maine	3B 2H														3B 2H
Maryland	2B	8B 2H	3B	8B 3H	1B										22B 5H
Massachusetts	2B	2B	2B 1H	9B 10H	1B	1B 2H									17B 13H
Michigan	14B 5H	2B	2B 1H	2B	1B 2H	1B 1H	1B	1B							24B 9H
Minnesota	* —	2B*	* —	1B	13B 3H		2B 2H								18B 5H
Mississippi	8B 3H														8B 3H
Missouri	11B*	3B 1H	17B* 8H	3B 1H	2B										36B 10H
Montana	2B 1H														2B 1H
Nebraska	1B 1H	2B	7B* 2H	* —											10B 3H
Nevada	3B	3B 3H													6B 3H
New Hampshire	3B 1H														3B 1H
New Jersey	4B 2H	5B 2H	3B 1H	5B 1H	2B 2H										19B 8H

Table 5.— Number of CT Head and Body Scanners by Health Service Areas (May 1980)–continued

State	Health service area (by number)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
New Mexico	5B 5H	* —													5B 5H
New York	7B 6H	7B 1H	4B 3H	1B* 1H	1B 3H	7B 3H	34B 11H	10B 4H							71B 32H
North Carolina	2B	3B 4H	5B 3H	6B 2H	2B 1H	3B 1H									21B 11H
North Dakota	3B 1H	1B*	* 1H												4B 2H
Ohio	4B* 4H	3B 2H	2B	4B 1H	7B 4H	3B	3B	4B 1H	12B 3H	4B 1H					46B 16H
Oklahoma	13B 2H														13B 2H
Oregon	9B	3B 2H	1B 1H												13B 3H
Pennsylvania	19B 7H	2B 1H	1B 1H	7B 1H	1B 1H	16B 8H	2B 2H	1B*	3B						52B 21H
Rhode Island	2B 1H														2B 1H
South Carolina	2B 1H	1B	1H	2B —	*										5B 2H
South Dakota	3B														3B —
Tennessee	3B* 1H	5B 1H	2B* 2H	4B 1H	1B	4B 3H									19B 8H
Texas	1B 1H	2B 2H	2B 4H	1B	12B 9H	4B 3H	3B	2B 2H	7B 5H	1B 2H	22B 15H	2B			59B 43H
Utah	7B	*													7B —
Vermont	2B														2B —
Virginia	1B 4H	3B 2H	4B 1H	5B 3H	5B 3H	* —									18B 13H
Washington	8B 10H	3B	3B 1H	5B											19B 11H
West Virginia	7B 3H														7B 3H
Wisconsin	2B 2H	7B 5H	2B 1H	2B	2B	2B 1H	* —								17B 9H
Wyoming	2B														2B —
Puerto Rico	4B 1H														4B 1H

Key to symbols: H = head scanner; B = body scanner.
*Interstate health service areas:
Alabama 7 and Georgia 5.
Arizona 4, and New Mexico 2, and Utah 2.
Georgia 1 and Tennessee 3.
Georgia 4 and South Carolina 5.
Illinois 10 and Iowa 3.
Illinois 11 and Missouri 3.
Iowa 1 and Nebraska 4.
Iowa 2 and Nebraska 3.
Kansas 4 and Missouri 1.
Kentucky 3 and Ohio 1.
Minnesota 1 and North Dakota 2.
Minnesota 2 and Wisconsin 7.
New York 4 and Pennsylvania 8.
Tennessee 1 and Virginia 6.

SOURCE Office of Technology Assessment

sons, Florida (3.0), Washington (2.8), New York (2.4), and Vermont (2.3). A number of States have no private office scanners.

The proportion of scanners located in private offices versus hospitals raises concern over the issue of access. Data on the hospitals by type and size do little to assuage this concern. Tables 6 and 7 present data on the distribution of CT scanners by type of facility and for short-term, general community hospitals, by size of hospital. Of a total of 5,881 short-term general hospitals (12), 1,01.5 or 17.3 percent have CT scanners. As shown in table 7, 361 hospitals, or 35.6

Table 6.—Distribution of CT Scanners by Type of Facility (May 1980)

	Facilities with CT scanners		CT scanners	
Type of facility	Number	Percentage of total	Number	Percentage of total
All hospitals.	1,041	78.7%	1,175	79.9%
Community hospitals	(1,015)	(76.7)	(1,147)	(77.9)
Other short-term hospitals[b].	(26)	(1.9)	(28)	(1.9)
Mobile scanners	18	1.4	18	1.2
Office and clinics	264	19.9	278	18.9
Total	1,323	100.0°/0	1,471	100.0%

[a]Includes proprietary, public, and voluntary community hospitals
[b]Includes 17 VA hospitals and 8 armed forces hospitals

SOURCE: Office of Technology Assessment and American Hospital Association

Table 7.—Distribution of CT Scanners in Community Hospitals" by Hospital Size (May 1980)

	All hospitals		Hospitals with CT scanners		
Size of hospital	Number	Percentage of total	Number	Percentage of total	Number of CT scanners
O- 99 beds. .	2,833	48.20/0	14	0.5%	14
100-199 beds. .	1,401	23.8	129	9.2	133
200-299 beds. .	713	12.1	218	30.6	225
300-399 beds. .	380	6.5	220	57.9	228
400-499 beds . .	243	4.1	170	70.0	187
500 and over . .	311	5.3	264	84.9	360
Total.	5,881	100.0%	1,015	1 7.3=X.	'1 ,147

[a]Includes proprietary, public, and voluntary hospitals Does not Include federally supported hospitals

SOURCE Office of Technology Assessment and American Hospital Association

percent of the total community hospitals having CT scanners, are less than 300 beds in size.

Of the total short-term general hospitals, 1,832 are supported by State and local governments, and only 161, or 8.8 percent, have CT scanners. When size is taken into consideration, this point becomes even more striking. A short-term general hospital with 500 beds or more is almost certain to have an active emergency room, a neurosurgery service, and other specialized and acute care services that virtually require a CT scanner for the provision of appropriate care. But of the 47 local-government-supported community hospitals of at least 500 beds, only 32 have CT scanners. New York City alone has six such hospitals with no CT scanner. These include Bellevue Hospital (1,258 beds),[4] Harlem Hospital Center (884 beds), Metropolitan Hospital (754 beds), and the City Hospital of Elmhurst (816 beds). Other important public hospitals in the United States without CT scanners include Cook County Hospital in Chicago (1,326 beds), D.C. General Hospital in Washington, D. C. (600 beds), and San Juan Municipal Hospital in San Juan, Puerto Rico (687 beds). Not only are the patients of these hospitals poor, but they are often members of minority groups.

The problems related to the distribution of CT scanners in hospitals are not confined to those in urban ghettos. The Department of Defense and the Veterans Administration (VA) operate large hospital systems. Although these hospitals do not run the busy emergency rooms of the urban public hospitals, they do serve large populations. Only 17 of 171 VA hospitals and 8 of 135 armed forces hospitals currently have CT scanners. There are 44 VA hospitals across the country with 500 beds or more that have no CT scanner. (The average bed size of this group of VA hospitals is over 800 beds.)

[4]Money is currently budgeted for a scanner for Bellevue Hospital.

There is 1 armed forces hospital of over 500 beds with no scanner. (See app. C for more details on the VA and armed forces' policies toward CT scanners.)

As shown in table 7, 84.9 percent of short-term general hospitals of over 500 beds now have at least 1 CT scanner; 264 such hospitals have 360 scanners. Thus, there is a fair proportion of community hospitals with more than one scanner. This category is comprised of several types of hospitals including voluntary, public, and proprietary. Most of the community hospitals with CT scanners are voluntary. The category of public hospitals includes hospitals supported at the level of hospital district, city, county, and State governments, but excludes federally supported hospitals. Of the State-supported hospitals with over 500 beds that have CT scanners, all but one are affiliated with the State university. This reflects the concentration of diffusion of CT scanners in hospitals affiliated with virtually all medical schools in the country. However, not all university teaching hospitals are large, and some major ones lack a CT scanner (e.g., Beth Israel in Boston).

The plight of local-government-operated hospitals has already been discussed above. The case of proprietary hospitals also illustrates inequity in distribution of CT scanners. There are a total of 81 such institutions with CT scanners. In general, proprietary hospitals tend to be smaller, in terms of bed size, than other community hospitals. Of the 80 proprietary hospitals with scanners, 40 have less than 200 beds.

In total, there are 97 hospitals of all types with 500 beds or more which are still without a CT scanner. The 44 VA hospitals constitute almost half of these, or 45.4 percent. The 15 large, publicly supported urban hospitals and 1 military hospital discussed above comprise another 16.5 percent, and the remaining 36 hospitals, or 40.3 percent, are "private" community hospitals, including voluntary and proprietary hospitals.[5] There are, then, 51 community hospitals of 500 beds or more without scanners, which account for the 16.5 percent of all hospitals of that type and size that are still without CT scanners.[6]

Based on these data, a seemingly clear case of maldistribution of scanners within the category of hospital settings emerges. It is not clear, however, which type and size of hospital may derive the greatest benefit from having a CT scanner. Modest evidence from a new study suggests that scanners may have a greater diagnostic and therapeutic impact in *a* public university-affiliated hospital than in a private medical center with a similar affiliation (14). Yet it is these hospitals for whom the economic and technical support a scanner requires may be less feasible.

The capital expenditures and technical support required may prohibit the hospital of less than 200 or 300 beds from installing a scanner. Table 7, showing the proportion of community hospitals by bed size and the proportion of each of these groups that has a CT scanner, would lend support to this hypothesis.

This analysis of type of setting, and type and size of hospital, suggests another issue besides that of institutional distribution of scanners: The commercial market for CT scanners, at least in voluntary community hospitals of appreciable size (500 beds), may be approaching saturation. Such a conclusion, however, is subject to the qualification of type and generation of scanner being considered. Thus far, in discussing the diffusion and distribution of scanners, the technical capabilities (beyond those indicated by dedicated head v. total body CT units) of scanners have not been explicitly considered. Clearly, any statements regarding saturation of the market are a function of the fact that these facilities merely have a CT scanner—not that they have the CT scanner of a type that they might need or desire. One outcome of the "rush" for scanners in 1975 was that a great many hospitals purchased scanners representing the state of the art of CT technology at that time—typically an early head scanner. Since that time, improvements in scanning speed and

[5]The discrepancy of two hospitals from the data in table 6 is due to the fact that two large hospital systems were counted as one hospital each in the American Hospital Association data, In OTA's analysis, the scanners were listed under individual hospitals.

[6]There is also one Public Health Service hospital not included in these figures that has .500 beds but lacks a CT scanner.

image resolution, as well as the potential to reduce radiation exposure to patients, have occurred in successive models of scanners, creating a concomitant demand for these new state-of-the-art CT scanners,

In considering the question of whether health planning policies have influenced diffusion, either in terms of the aggregate number of scanners, the rate of purchase, and/or market saturation (as qualified above), the concomitant effects of the distribution and technical capability of existing operational scanners have been ignored. The focus on whether these policies have been effective in either limiting diffusion or promoting market saturation reflects concern for only one of the two objectives of the health planning laws—the containment of costs. But if, in the attempt to control diffusion, the law and related regulation can be shown to have effected an inequitable distribution of medical technology that is inadequate for the needs of various health care providers, then they have failed to assure the second objective—namely, ensuring access to and quality of care. Perhaps more important is the issue of whether existing health planning policies will be able to redress distributional inequities and resolve problems related to appropriate technology in the future (see ch. 3).

TRENDS IN THE TYPE AND MANUFACTURE OF SCANNERS

The CT scanner market has undergone dramatic changes since EMI, Ltd., developed the first commercial head scanner in the early 1970's. By May 1980, there was a striking change in type of scanner being sold (see table 8). Only slightly more than half of the EMI scanners are now head scanners, compared to 92 percent of the EMI scanners installed as of May 1977, Body scanners have increased their domination of the market, and by May 1980, almost 69 percent of operational scanners were body scanners. During the 24 months from January 1978 through December 1979, however, Ohio-Nuclear installed 83 head scanners.[7]

Since the sale of the first scanner in this country by EMI in 1972, the CT market has undergone "see-saw" changes in both the number of companies manufacturing CT equipment and in

[7]Comparison with FDA data on scanners reported installed indicates that a good portion of these were the new lower priced scanners.

Table 8.—Manufacturers of CT Head and Body Scanners in Use (May 1980)

Manufacturer	Head scanners: Number	Head scanners: Percentage of total	Body scanners: Number	Body scanners: Percentage of total	Total scanners: Number	Total scanners: Percentage of total
EMI, Ltd.	284	61 .60/0	267	26,40/.	551	37.5%
Ohio-Nuclear	109	23.6	309	30.6	418	28.4
General Electric	16	3.5	221	21.8	237	16.1
Pfizer	—	—	107	10.6	107	7.3
Artronix	28	6.1	4	0.4	32	2.2
Syntex	11	2.4	17	1.7	28	1.9
Picker	—	—	22	2.2	22	1.5
Elscint	—	—	13	1.3	13	0.9
Varian	—	—	16	1.6	16	1.1
AS&E	–	—	11	1.1	11	0.7
Philips	—	—	10	1.0	10	0.7
Omni	9	1.9	—	—	9	0.6
Other[a]	3	0.6	14	1.4	17	1.2
Total	460	100.0%	1,011	100.0%	1,471	100.0%

[a]Three Companies—Neuroscan, Siemens, and CGR

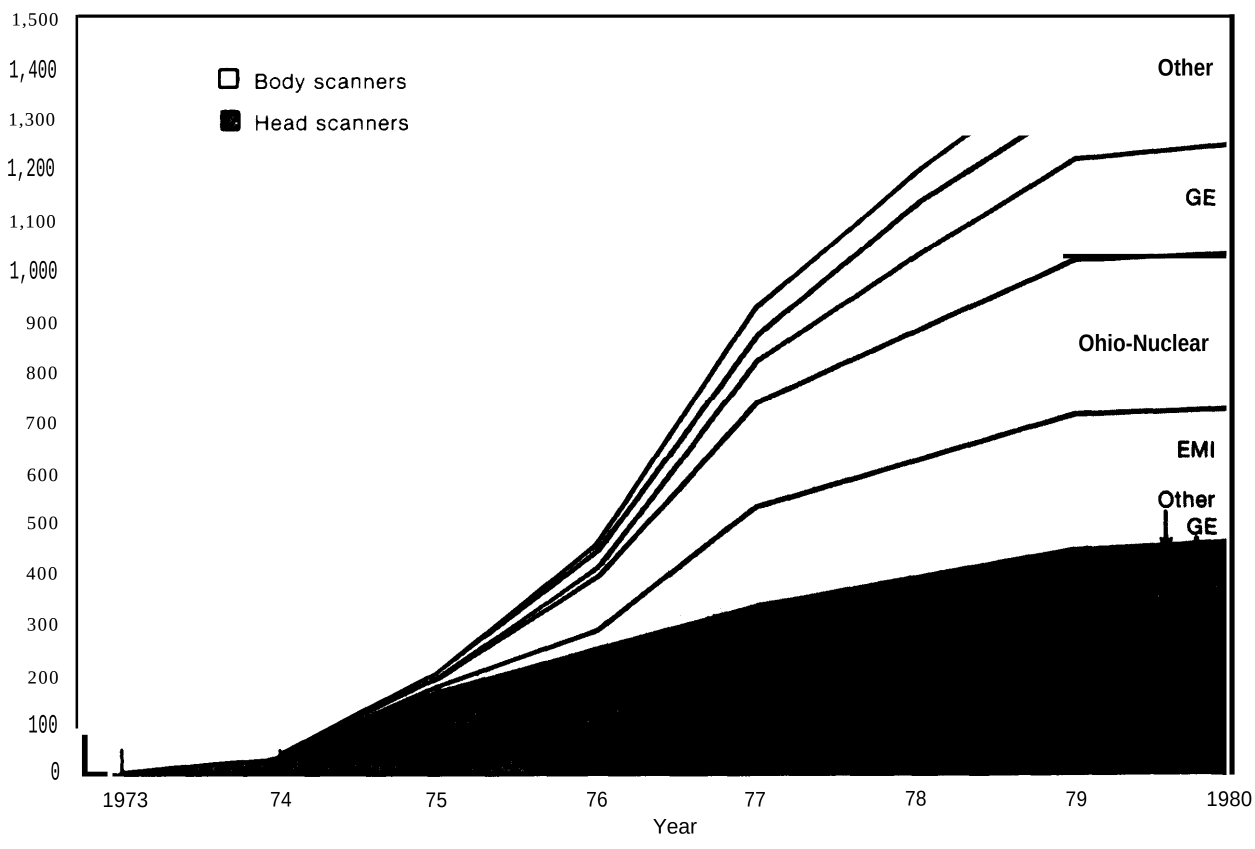
SOURCE Off Ice of Technology Assessment

their respective shares of the CT market. EMI dominated the American (and world) market through mid-1975 (see figure 4). Although six other companies were marketing CT scanners in the United States by May of 1977, EMI still had sold almost 60 percent of all operational scanners at that time.

However, the rapidly increasing number of new companies entering the market, as well as the new generations of scanners they introduced to the commercial marketplace, brought about some abrupt changes in the share of the market controlled by early manufacturers. By March 1978, there were 15 companies worldwide that had CT scanners in operation: Only 4 of these (EMI, Pfizer, General Electric (GE), and Siemens) had ever manufactured a rotate and translate, dual-detection scanner; 7 more of these (Philips, Elscint, Picker, Ohio-Nuclear, Syntex, Hitachi, and CGR) had entered the market with a rotate and translate, multiple detection scanner; and 4 more (Varian, Artronix, Searle, and American Science and Engineering (AS&E)) had entered with a rotate-only scanner (see table B-3 in app. B) (65,120).

The most dramatic change in the U.S. market share occurred in 1977 with the sharp increase in the number of scanners installed by GE. This is primarily attributable, not to expansionary market trends, but to GE's introduction of its new rotate-only scanner (which had been pioneered by that company) to the commercial market. Both GE and Ohio-Nuclear expanded their share of the market during 1978, so that by 1979, EMI's share had fallen to 40 percent of operational scanners. By 1980, EMI's share had

Figure 4.—Cumulative Number of CT Scanners Installed, by Manufacturer



SOURCE *Off Ice of* Technology Assessment been further reduced to about 37 percent. Figure 4 shows the changing relative market shares of manufacturers, as measured by the proportion of operational scanners in the United States, over the past several years.

Another indicator of changing market shares is worldwide sales of scanners. According to one source, estimated 1979 sales yield a ranking of manufacturers as follows: GE ($100 million), Siemens ($50 million), Johnson & Johnson (Ohio-Nuclear) ($45 million), both Picker and Pfizer ($30 million), EMI ($15 million), Elscint ($l4 million), Philips ($10 million), and both Toshiba and Hitachi ($5 million)[8] (48). Naturally, different companies tend to be more successful in certain countries, usually their own or contiguous countries. For example, Siemens, a West German company, tends to dominate the market in West Germany. Despite an early lead by EMI, the Japanese companies are gaining dominance in Japan. Siemens dominates in Belgium, with CGR, a French company, having major success as well. Other countries have a larger spread of manufacturers, although EMI tends to have larger percentages because of its early domination of the market. GE is apparently the only U.S. company that has had significant success outside of the United States (33).

The precipitous decline in both the number of scanners sold and in scanner sales in 1977 and 1978 marked the beginning of the end of previous expansionary market trends. As the first, and for many years dominant, manufacturer of CT scanners, EMI aptly illustrates the various aspects of the troubled CT market over the past few years, Following a $29.1 million profit for the fiscal year of 1977 (115), the medical electronics division of EMI, including the CT scanner business, incurred major losses in both fiscal years 1978 (– $28.7 million) and in 1979 (– $27.8 million) (172). In early 1979, it was reported that EMI had begun to seek a merger of its medical division with a U.S. company in order to cushion these losses (31). In December 1979, EMI was acquired by Thorn Electrical Industries, Ltd., of Great Britain, but in April 1980, Thorn attempted to sell its newly acquired EMI scanner interests with a sale to GE (26,165). GE sought an advisory opinion from the U.S. Department of Justice, however, and was informed that such a takeover would probably be found to violate antitrust law. The upshot was that GE only acquired EMI's non-U. S. operations, leaving EMI's U.S. operation in limbo. In 1977 and 1978, EMI initiated litigation against Technicare of Ohio-Nuclear (45), Pfizer (113), and GE (@I). The suits filed by EMI against these companies sought damages for alleged infringements of its many patent rights on the CT scanner.[9] Part of GE's agreement in purchasing EMI was the settlement of this patent litigation (26).

Further signs of the troubled CT scanner market are evident in the trend toward market consolidation as measured by the number of other companies that have merged, are seeking to sell, or have already sold their scanner interests. The depressed state of the CT scanner market in 1978 is reflected by the fact that by the end of that year, at least two companies (Searle and Syntex) went out of the CT scanner business (26,43); another (AS&E) sold its rights to market and produce the scanner it had pioneered (to Pfizer) (42); and one of the leading manufacturers of body scanners at that time (Ohio-Nuclear) was acquired by the single newcomer to the CT scanner market (Johnson & Johnson) in 1978, (44). In 1979, Varian also put its CT scanner division on the market, with the intent of eliminating the divison if it could not find a buyer (114). By October 1979, Neuroscan was no longer making scanners, and Artronix had notified the Food and Drug Administration (FDA) that it would cease to market scanners (90).

Thus since the beginning of 1978, eight companies, EMI, Searle, Syntex, AS&E, Ohio-Nuclear of Technicare, Varian, Neuroscan, and Artronix, have left the CT market (in some fashion), and only one, Johnson & Johnson, has entered it. As of September 1979, there were 10 companies which still had CT scanners certified as meeting FDA performance standards marketed in the United States (90): These included

“Data collected by U.S. manufacturers indicate that the estimate for the Japanese companies is much too low.

[9]In a separate agreement with EMI, Johnson & Johnson agreed to pay EMI $15 million to drop suit against Technicare of Ohio-Nuclear (44).

GE (United States), Siemens (West Germany), Johnson & Johnson (formerly Ohio-Nuclear, United States), Picker (United States), Pfizer (United States), EMI (Great Britain), Elscint (Israel), Philips (Netherlands), CGR (France), and Omni Medical (United States).

With the apparent exit of EMI in late 1979, nine companies remain. Counting the three Japanese companies (Shimadzu, Toshiba, and Hitachi), there are now 12 companies worldwide still manufacturing CT scanners. It is believed that the remaining market for scanners will not support all of these companies, however, and further consolidation is predicted for the future (26).

Manufacturers have cited Federal interventions as the culprit behind the millions of dollars lost on the CT scanner market over the last few years. Specifically, this calamitous turn of events has been blamed on the implementation of the health planning laws enacted in 1974 and on the consequent certificate-of-need (CON) regulations imposed through local health systems agencies (HSAs) since 1976 (26,65). However, it is also true that the expansionary trends exhibited in the mid-1970's could not continue forever: The number of scanners that could ultimately be sold was not limitless, and that number could have been reached by far fewer manufacturers than the number of manufacturers that rushed to share in profits such as those EMI was realizing in 1975[10], In addition, companies like EMI in 1976 which in 1976 faced a backlog of 250 unfilled orders, had geared up production capacities to meet the wildly escalating demand for scanners. Thus, it appears that there may have been substantial overestimation of the potential market for scanners on the part of manufacturers.

In the wake of this controversy, there have also been modifications in marketing strategies, some of which appear to be in response to the CON review process and specific regulations. The advent of the new low-priced scanners, in particular, has drawn the attention of policymakers. At least three companies have models of a head scanner having a list price of less than $200,2000 (49). Four of these models sell for less than $l50,000, the threshold figure at which CON approval is required for purchase. One company has a body scanner whose purchase price is less than $100,000, plus maintenance costs (49). The interim regulations issued in April 1979 by the Bureau of Health Planning (BHP), however, have countered this particular strategy as a means of skirting the purview of CON review (see ch. 3).

According to FDA data on scanners reported as installed between June 1978 and June 1979, there were 39 scanners listed that sold for less than $200,000 (95). Ohio-Nuclear has been particularly active in selling these scanners, having sold 16 of the model 150 Delta-Scan head scanner that costs approximately $145,000 and 6 of the model 110 Delta-Scan that is priced at $96,500 (49). Omni Medical has also been active in the promotion and sale of these scanners and has reportedly concentrated its production in a low-cost (sub-$l50,000) highly reliable cranial CT scanner (40). The technical capabilities of these scanners are more limited than those of the more expensive and technically sophisticated models, and this reduces their appeal to many potential buyers. Still, these new lower priced scanners avail themselves to a new market of small hospitals and private offices (49).

Another strategy of some manufacturers has been to upgrade and refurbish older scanners; this includes modifying head scanners to body units. Several of the "new" cheaper scanners are actually older scanners that have been bought back, or traded in on more advanced newer equipment, and then refurbished by the manufacturers (90). EMI and Pfizer have both been engaged in programs of updating older models to the latest specifications. Generally, refurbishing can be done for less than $100,000. The change in definition from CT scanning equipment to CT scanning services (again by virtue of the April 1979 interim regulations issued by

[10]A. U.S. market estimate in 1975 prepared by Kidder, Peabody, and Co., predicted that a total of 1,425 CT units would be in place by the end of 1980. In fact, this number was probably attained by the end of 1979 (according to manufacturers' sales data). In reporting the above projection, however, it is interesting to note that the author, critical of the imposition of health planning measures in 1976, noted: "The growth curve was well on the way to reaching that level (1425) until it encountered the Federal and State CON laws that were imposed" (65).

BHP), however, means that changes such as upgrading a head to a body machine are subject to CON review (see ch. 3).

Another strategy manufacturers have used to diversify their CT markets has been to install scanners in a mobile environment. At least two companies are now selling various models of their scanners installed in special vehicles. According to OTA's data, the number of mobile scanners as of February 1979 had doubled, going from 7 to 14 in less than a year; by May of 1980, the number had increased further to 18. For a while, the market potential for mobile units appeared substantial, since these scanners were not subject to CON review. It was also expected that medicare would soon begin to pay for scans done on mobile scanners. In anticipation of that announcement by medicare, however, mobile scanners were placed within the purview of CON review (once again, under the interim regulations issued by BHP in April 1979) (see ch. 3). Furthermore, when the announcement did come from medicare, the regulations for reimbursement stipulated that reimbursement would be made only for scans done on CON-approved mobile scanners (85). Nonetheless, the number of mobile scanners seems certain to increase. One company is now servicing the needs of 44 hospitals in southern California for CT scanners (166), and that company reports to OTA that it expects to expand its present stock of 21 operational scanners (as of October 1980) by 1 to 1 1/2 per month. This development is clearly to the advantage of the smaller hospitals that cannot support a scanner on their own, and it may well be an efficient way to provide access to CT scanning services (70). So far, however, Federal policy with respect to mobile scanners has been conservative, and sharing has not been encouraged.

It would seem fair to conclude that manufacturers have attempted to place the blame for the changes that have occurred in the CT scanner market over the past 2 years on cost-conscious Federal policies. Although it is unlikely that these policies are solely to blame for the rather abrupt turn of market events, it is clear that the trend in Federal policies toward the CT scanner market over the past 2 years has been one of increased restraint in a kind of "cat and mouse" game with the manufacturers in the name of cost containment. It would seem that Federal policymakers and manufacturers alike could benefit from taking a broader, more comparehensive view of the forces shaping these events, and developing a more balanced appreciation of the two objectives of ensuring access and quality care and containing costs. One of the forces, research and development of existing and emerging diagnostic imaging modalities with which CT is competing (or will eventually compete) for a place in medical practice, is discussed in appendix B. Federal policies toward CT scanners and changes in those policies since 1978 are summarized in the next chapter,