Imaging the Heart: Cardiac Scintigraphy and Echocardiography in U.S. Hospitals (1983)

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The rapid growth of cardiac catheterization has raised questions about the availability of less costly, "noninvasive" tests such as cardiac scintigraphy and echocardiography. To assess their availability and rates of use, we surveyed 3,778 non-federal short-term U.S. hospitals in June, 1983. Overall, 2,605 hospitals (69%) offered ^{201}Tl myocardial perfusion scans, 2,580 (68%) ^{99m}Tc equilibrium gated blood pool scans, and 2,483 (67%) cardiac shunt scans; 1,679 hospitals (44%) offered M-mode and/or 2-dimensional echocardiography, and 768 (20%) pulsed Doppler echocardiography. Volumes of procedures varied enormously among hospitals capable of performing them. High volumes of both scintigraphy and echocardiography were performed in a small number of hospitals. Larger, voluntary, and teaching hospitals performed higher volumes of both procedures. Despite widespread availability of these "noninvasive" technologies, high volumes of both cardiac scintigraphy and echocardiography procedures are concentrated in a small number of U.S. hospitals.

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Cardiac imaging by scintigraphy and echocardiography have been among the fastest growing diagnostic technologies in medicine during the past 15 years (*1,2*). Because there has been no previous examination of national data, we undertook this study to examine the presence of these technologies in U.S. hospitals.

Following development of the basic technology for nuclear medicine in the late 1950s and 1960s, rapid growth in its clinical applications occurred during the 1970s. Between 1971 and 1975 the use of all nuclear medicine procedures per 100 hospital admissions nearly doubled. In 1978, 6.5 million nuclear studies were performed in the U.S.; by 1981, the number had grown to 9.7 million scans (*1*). Cardiac scintigraphy became possible in 1975 when the first practical computer systems for technetium-99m (^{99m}Tc) equilibrium gated blood pool scans became available. In 1977, the Food and Drug Administration approved thallium-201 (^{201}Tl) as a myocardial imaging agent, enabling the performance of perfusion and redistribution scans (*1*).

Diagnostic ultrasound blossomed in the mid-1970s with the introduction of instruments permitting a wide variety of applications. After one-dimensional (M-mode) echocardiography was introduced, the equipment and technology made rapid progress (*2*). The development and evolution of two-dimensional (2-D) real-time echocardiography in the late 1970s provided higher resolution images and better diagnostic sensitivity (*2,3*). More recently, the pulsed Doppler and continuous wave ultrasound techniques have been developed and applied to 2-D echocardiography (*2,4*).

Though there has been no direct examination of the growth of cardiac imaging, estimates from marketing surveys and manufacturers have suggested an extraordinarily rapid diffusion of these technologies. In 1978 an estimated 227,000 cardiac scintigrams were performed in the U.S.; by 1981, this estimate had grown to 1.5 million scans per year (*1*). Pozen and colleagues, extrapolating from a survey of a stratified sample of 200 U.S. hospitals, estimated that by 1979 2,106 hospitals had the technical capabilities to perform cardiac scintigraphy (*5*). In 1982 the Office of Technology Assessment (OTA) estimated that about half of the 7,100 hospitals in the U.S. had nuclear medicine departments capable of performing cardiac scintigraphy (*1*). The use of echocardiography has also increased rapidly, at an estimated rate of more than 30% per year between 1979 and 1982. This growth was probably a result of the development of the 2-D echocardiogram. Though the rate slowed somewhat thereafter, it remains

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substantially greater than that of many other diagnostic technologies (*2*).

This study was undertaken to assess directly the extent of diffusion and rate of use of these "noninvasive" cardiac imaging modalities in U.S. hospitals by 1983. We examined:

- The proportion and types of hospitals that had cardiac scintigraphy and echocardiography by 1983;
- The extent of utilization of six representative procedures, including ^{201}Tl perfusion and redistribution scans, ^{99m}Tc equilibrium gated blood pool scans, cardiac shunt scans, M-mode echocardiography, 2-D echocardiography and pulsed Doppler 2-D echocardiography;
- The organizational and ownership characteristics of hospitals offering these procedures;
- The availability of equipment needed to perform such imaging; and
- The relationship of hospital staffing and recruitment activities to such imaging.

The data provide indirect evidence of the extraordinarily rapid diffusion of these new "noninvasive" technologies by 1983.

MATERIALS AND METHODS

In order to study the distribution and use of cardiac imaging modalities in the U.S., we conducted a national survey of non-federal short-term general hospitals and other special hospitals (*6*). The responses to the questionnaire items relating to cardiac nuclear imaging and echocardiography were analyzed and the results are reported below. Information from the American Hospital Association's annual survey (*7*) also contributed to the findings in this study.

Survey of Specialized Clinical Services, 1983. A fifteen-page questionnaire, designed to obtain information on the availability and utilization of selected specialized clinical services, was mailed to all 5,898 short-term general hospitals in the U.S. in June 1983; 3,778 hospitals (64%) responded by September 1983. Although the survey was mailed to the chief executive officer of each hospital, the instructions suggested that it be routed to specific department heads for completion. The respondents are similar to the entire universe of U.S. hospitals in terms of ownership, census division, and availability of standard hospital facilities (such as emergency departments or maternity care services). However, a slightly higher response rate among larger hospitals means that we have proportionately more complete information about those larger hospitals (>100 beds) that are also more likely to have nuclear imaging or echocardiography facilities (*6*).

In the section on cardiac nuclear imaging, hospitals were asked if they performed scintigraphic procedures, and, if so, the estimated number of certain procedures performed during the month before the survey: ^{201}Tl myocardial perfusion scans, ^{99m}Tc equilibrium gated cardiac blood pool scans, and cardiac shunt studies. For the first two procedures, stress/exercise and redistribution/rest tests were counted as separate studies even if performed on a single patient. They were also asked about the availability in their hospital of several types of equipment, including scintillation camera, nuclear medicine computer, and computerized analysis of ventricular function.

In the section on echocardiography, hospitals were asked if three types of equipment were available, and, if so, the estimated number of procedures performed in the month before the survey: real-time units with 2-D sector scans, dedicated cardiac M-mode units, and built-in or added-on pulsed Doppler units. Portable equipment used by multiple hospitals was not included.

Also, each hospital was asked if certain specialists were on its staff (cardiologists, cardiovascular surgeons, nuclear medicine specialists) and if such specialists had been recruited during the previous three years.

American Hospital Association Annual Survey, 1982. This survey provided data on such hospital characteristics as size, regional location, ownership, and medical school affiliation (*7*). The American Hospital Association defines hospital ownership as state or local government, voluntary (short-term, general, non-profit, community), or proprietary (for-profit) hospitals.

RESULTS

Cardiac scintigraphy is offered by 69% of U.S. hospitals responding to the survey. Overall, 2,605 hospitals (69%) offer ^{201}Tl myocardial perfusion scans, 2,580 (68%) offer ^{99m}Tc equilibrium gated blood-pool scans, and 2,483 (66%) cardiac shunt studies. Cardiac scintigraphy is reported by three-quarters (75%) of voluntary hospitals, but only by about two-thirds (64%) of proprietary hospitals and slightly more than half (56%) of state and local government hospitals. As might be expected, hospitals affiliated with medical schools are much more likely (90%) than non-affiliated hospitals (65%) to offer these procedures. Larger hospitals are more likely to offer cardiac scintigraphy; over 80% of 100–199-bed hospitals and over 90% of 200–299-bed hospitals perform these tests. A surprising percentage of small hospitals offer cardiac scintigraphy; even among hospitals with only 50–99 beds, over 50% have this capability.

M-mode or 2-D echocardiography is offered by 1,679 (44%) of U.S. hospitals responding to the survey. Pulsed Doppler echocardiography is offered by only 768 (20%) of respondents. Echocardiography is reported by half (52%) of voluntary hospitals, but only by 39% of proprietary and 40% of state and local government hospi-

tals. Hospitals affiliated with medical schools were much more likely (74%) than non-affiliated hospitals (39%) to offer echocardiography. For hospitals with fewer than 200 beds, there is a direct relationship between hospital size and performance of echocardiography: 4% of 1–49 bed, 12% of 50–99 bed and 27% of 100–199 bed hospitals offer echocardiography. For hospitals with more than 200 beds, an inverse relationship exists: 20% of 200–299 bed, 15% of 300–399 bed, and 10% of 400–499 bed hospitals perform these tests.

Table 1 shows the volume distribution of procedures during the month before the survey. On average, hospitals report performing 12.0 myocardial perfusion scans per month and 13.2 equilibrium gated blood scans. Although the majority of U.S. hospitals have adopted cardiac scintigraphy by 1983, the volume of procedures varies widely, from 0 to 240 myocardial perfusion scans and 0 to 560 equilibrium blood pool scans per month. Approximately 20% of hospitals perform 18 or more of each per month, but this small percent of hospitals accounts for more than 80% of the overall number of tests performed. Hospitals that perform 17 or fewer tests per month account for only 20% and 16% of the overall volume of myocardial perfusion and blood pool scans, respectively. No myocardial perfusion scans during the previous month were reported by 43% of hospitals and no equilibrium gated blood pool scans by 47%. (Hospitals that report 0 procedures during the month before the survey have the equipment and capability of performing the tests, but may be assumed to perform a very low volume of tests.)

For cardiac shunt studies, a procedure generally performed on children, the picture is different. Hospitals report performing a mean of only 0.6 such scans per month; 90% of hospitals report 0 procedures during the previous month. The 1,426 cardiac shunt studies were evenly distributed among the 10% of hospitals performing them during the prior month.

On average, hospitals report performing 108.9 echocardiograms per month. The volume varies from 0 to more than 1,000 echocardiograms per month. About 50% of hospitals perform more than 70 echocardiograms per month, but these hospitals account for 86% of the overall number of echocardiograms performed. Only 4% of hospitals having echocardiography capability performed 0 scans during the month before the survey.

In Table 2, data are presented to explore the charac-

TABLE 1
Distribution of Volume of Cardiac Imaging Performed in U.S. Hospitals (1983)

Procedure	Tests per month (mean ± s.d.)	Test volume during month preceding survey 0	1–17	18+	Total
Myocardial perfusion*	12.0 ± 0.5				
No. of hospitals		1,106	968	531	2,605
Percent of hospitals		42.5	37.2	20.4	100
No. of tests in all hosp. in vol. category		—	6,205	25,012	31,217
Percent of all tests by hosp. in vol. category		—	19.9	80.1	100
Equilibrium gated blood pool*	13.2 ± 0.6				
No. of hospitals		1,223	785	572	2,580
Percent of hospitals		47.4	30.4	22.2	100
No. of tests in all hosp. in vol. category		—	5,548	28,595	34,143
Percent of all tests by hosp. in vol. category		—	16.3	83.8	100
Cardiac Shunt	0.6 ± 0.1				
No. of hospitals		2,228	241	14	2,483
Percent of hospitals		89.7	9.7	0.6	100
No. of tests in all hosp. in vol. category		—	755	671	1,426
Percent of all tests by hosp. in vol. category		—	53.0	47.1	100

		Test volume during month preceding survey 0	1–70	71+	Total
Echocardiography (real time 2-D and cardiac M-mode scans)	108.9 ± 3.8				
No. of hospitals		65	779	836	1,680
Percent of hospitals		3.9	46.3	49.8	100
No. of tests in all hosp. in vol. category		—	24,841	154,189	178,767
Percent of all tests by hosp. in vol. category		—	13.9	86.2	100

* Stress/exercise and redistribution/rest tests were counted as separate procedures even if performed on a single patient.

TABLE 2
Characteristics of Hospitals Performing Cardiac Imaging by Volume per Month

	Volume of myocardial perfusion and equilibrium gated blood pool scans during month preceding survey*							
	0		1–17		18+		Total	
	%	n	%	n	%	n	%	n
Ownership								
State & local government	33.2	(319)	21.8	(163)	13.9	(126)	23.3	(608)
Voluntary	59.2	(568)	67.5	(504)	81.2	(737)	69.2	(1809)
Proprietary	7.6	(73)	10.6	(79)	4.2	(45)	7.5	(197)
	100%		100%		100%		100%	
Teaching								
Affiliated	5.8	(56)	12.5	(93)	46.4	(42)	21.8	(570)
Not affiliated	94.2	(904)	87.5	(653)	53.6	(487)	78.2	(2044)
	100%		100%		100%		100%	
Bed size								
Under 49	12.8	(123)	4.2	(29)	0.1	(1)	0.4	(143)
50–99	31.8	(305)	18.1	(124)	1.9	(17)	17.0	(446)
100–199	36.6	(351)	39.4	(270)	11.9	(108)	27.9	(729)
200–299	11.3	(108)	17.1	(117)	22.6	(205)	18.7	(490)
300–399	5.7	(55)	13.1	(90)	20.4	(185)	12.6	(330)
400+	1.8	(18)	8.2	(56)	43.2	(392)	17.8	(466)
	100%		100%		100%		100%	

	Volume of echocardiography (real time 2-D sector scans and cardiac M-mode scans) during month preceding survey							
	0		1–70		71+		Total	
	%	n	%	n	%	n	%	n
Ownership								
State & local government	32.3	(21)	23.8	(185)	13.4	(112)	18.9	(319)
Voluntary	63.1	(41)	66.6	(518)	81.8	(683)	74.0	(1243)
Proprietary	4.6	(3)	9.6	(75)	4.8	(40)	7.0	(118)
	100%		100%		100%		100%	
Teaching								
Affiliated	6.2	(4)	9.0	(70)	47.2	(394)	21.8	(570)
Not affiliated	93.8	(61)	91.0	(709)	52.8	(441)	72.1	(1211)
	100%		100%		100%		100%	
Bed Size								
Under 49	16.9	(11)	5.9	(46)	0.1	(1)	3.5	(58)
50–99	36.9	(24)	19.7	(153)	2.0	(17)	11.6	(194)
100–199	35.4	(23)	41.0	(319)	12.9	(108)	26.8	(450)
200–299	4.6	(3)	19.7	(153)	21.2	(177)	19.8	(333)
300–399	3.1	(2)	9.5	(74)	21.9	(183)	15.4	(259)
400+	3.1	(2)	4.2	(33)	41.8	(349)	22.9	(384)
	100%		100%		100%		100%	

* Stress/exercise and redistribution/rest tests were counted as separate procedures even if performed on a single patient.

teristics of hospitals that report very low, low to medium, or high volumes of the procedures during the month before the survey. For scintigraphy, hospitals are divided into three groups: those performing 0 myocardial perfusion and equilibrium gated blood pool scans during the prior month, those performing 1–17 procedures, and those performing 18 or more procedures. The two procedures are combined since the same physician specialists use the same basic equipment to perform each. In hospitals performing more than 17 procedures per month, a procedure is done on average every other day, indicating that the staff has considerable experience in administering the tests and interpreting their results. Similarly, for echocardiography, hospitals are divided into three groups: those performing 0 M-mode and 2-D echocardiograms during the

prior month, those performing 1–70 scans, and those performing 71 or more.

For cardiac scintigraphy, hospitals that report a higher volume of procedures are more often voluntary hospitals and hospitals affiliated with medical schools. Some 81% of hospitals doing 18 or more procedures are voluntary hospitals; 94% of hospitals doing 0 procedures are not medical school affiliates. The size of the hospital is also an important determinant of test volume. Only 14% of the 908 hospitals that report 18 or more procedures are smaller than 200 beds.

Similarly, for echocardiography, hospitals that report a higher volume of procedures are more often voluntary hospitals and hospitals affiliated with medical schools. Some 82% of hospitals doing 71 or more echocardiograms are voluntary hospitals; 94% of hospitals doing 0 procedures are not medical school affiliated. Hospital size again is an important determinant of test volume. Only 15% of the 835 hospitals reporting 71 or more echocardiograms are smaller than 200 beds.

Seventy-three percent of all 3,778 hospital respondents report either cardiac scintigraphy or echocardiography. Some 147 hospitals (5%) perform only echocardiography, while 1,082 (39%) perform only scintigraphy and 1,532 (56%) perform both. The volume of echocardiography for all hospital respondents is over three times that of scintigraphy; this ratio of greater than 3 to 1 is fairly consistent among hospitals reporting low and high volumes of echocardiography. Hospitals offering only scintigraphy report doing fewer scintigrams than hospitals offering both scintigraphy and echocardiography. Overall, the 1,532 hospitals that perform both scintigraphy and echocardiography account for 81% of the estimated total of 66,021 scintigrams reported during the month prior to survey.

Table 3 shows the availability of equipment in hospitals performing cardiac scintigraphy by volume of procedures done in the prior month. Scintillation cameras were common (85–96% of hospitals) in all volume groups. However, hospitals performing higher volumes were much more likely to have a nuclear medicine computer system to collect, process, display, and prepare copies of data from procedures, and to perform computer analysis to cardiac ventricular function. M-mode or 2-D echocardiography is more likely to be available in hospitals performing higher volumes of cardiac scintigraphy. In addition, cardiac catheterization facilities were much more common in such hospitals.

Finally, we examined hospital staffing and recruitment activities by volume of cardiac scintigraphy. As might be expected, 98% of hosptials performing a large number of myocardial perfusion and/or equilibrium gated blood pool scans (18 or more per month) have nuclear medicine specialists on staff. However, nuclear medicine specialists are available even in 75% of the very low volume institutions (0 scintigrams per month), indicating that other kinds of nuclear imaging are done. Cardiovascular surgeons are on the staff of 75% of high volume (18 or more procedures per month) hospitals, 50% of medium volume (0–17 procedures per month) and 28% of low volume (0 per month) hospitals. In addition, recruitment activities may be one indication of a hospital's plans to expand its volume of scintigraphy. More than 11% of high volume, 23% of medium volume and 18% of low volume hospitals had recruited a nuclear medicine specialist within the past three years. Cardiac surgeons had been recruited by 33% of high volume, 17% of medium volume, and 10% of low volume hospitals.

DISCUSSION

By 1983, over two-thirds of U.S. hospitals were imaging the heart using cardiac scintigraphy and echocardiography. Both procedures were more often performed in teaching hospitals and in larger hospitals. In addition, the majority of tests performed were done in hospitals reporting large monthly volumes of both tests and hospitals having available sophisticated equipment.

TABLE 3
Availability of Equipment in Hospitals Performing Cardiac Imaging by Volume of Scintigraphy

	Volume of Myocardial Perfusion and Equilibrium Gated Blood Pool Scans During Month Preceding Survey*					
	0		1–17		18+	
Equipment	%	n	%	n	%	n
Scintillation camera	89.5	(832)	95.6	(705)	84.9	(892)
Nuclear medicine computer	16.5	(158)	72.5	(533)	96.9	(866)
Computer analysis of ventricular function	10.6	(101)	69.6	(508)	96.9	(867)
Echocardiography (real time unit with 2-D sector scan or dedicated cardiac with M-mode)	51.3	(456)	69.4	(476)	96.1	(827)
Cardiac catheterization facility	5.5	(53)	31.0	(231)	87.5	(495)

*Stress/exercise and redistribution/rest tests were counted as separate procedures even if performed on a single patient.
Note: From five to 40 hospitals did not answer the item on various types of equipment on the questionnaire.

More hospitals report having scintigraphy equipment than echocardiography equipment; in hospitals performing both, however, the average volume of echocardiograms performed is considerably larger than that of scintigrams.

Cardiac scintigraphy, while it has fewer potential clinical applications, has several advantages over echocardiography (*1–2,8*). These advantages may explain why scintigraphy is much more prevalent among the hospitals responding to our survey. First, in many circumstances, it provides more quantitative data than echocardiography (*9–13*). Second, sophisticated nuclear medicine computers, found in 57% of the hospitals performing scintigraphy, allow computational capabilities. These computers increase the accuracy and decrease the tedium of such calculations as the left ventricular ejection fraction. Third, scintigraphy is relatively safe (e.g., no contrast toxicity), readily repeatable (for both inpatients and outpatients), and relatively "noninvasive" (e.g., less radiation exposure than with computed tomographic scanning and less risk than cardiac catheterization). Fourth, the patient charge for scintigraphy is moderate, and less than that for cardiac catheterization. Finally, scintigraphy requires only moderate technologist skills, and less physician involvement than cardiac angiography.

On the other hand, echocardiography has several potential advantages over scintigraphy (*2,14–16*). First, it is truly noninvasive, relying upon high frequency sound waves to generate an image, while scintigraphy requires the intravenous administration of a radionuclide. Echocardiography is safe in pregnancy. Second, in many centers the patient charge for echocardiography is less than that for scintigraphy. Because it requires less time, an echocardiogram usually costs half as much as a scintigram. Third, the equipment is more portable and generally has lower "down-time" and service costs than nuclear medicine equipment. Fourth, 2-D echocardiography has both real-time and stop-motion capabilities, and, when combined with use of Doppler instrumentation, can provide information on blood flow and cardiac output (*4*). Fifth, it requires only moderate technician training time and little physician involvement to perform. Sixth, echocardiography offers greater structural resolution than scintigraphy, offering superior evaluation of anatomical and structural detail. Finally, it has a greater range of potential clinical applications. These factors may account for our finding of a 3.3:1 average ratio of echocardiograms to scintigrams per month reported by hospitals that offer both procedures. (This ratio may also be due to the fact that physicians may perform echocardiography themselves, but must refer for scintigraphy to nuclear medicine specialists or radiologists.)

It should be noted that 27% of hospitals have the equipment for neither cardiac scintigraphy nor echocardiography. These may largely be small hospitals without cardiac catheterization or cardiovascular surgery facilities. Conversely, the equipment is more likely to be found in teaching hospitals where new technologies are developed and where cardiac catheterization and cardiovascular surgery facilities often are present.

Moreover, the volume of cardiac imaging procedures of both types are not evenly distributed across all U.S. hospitals. Rather, the vast majority of all cardiac imaging tests are performed by a small percentage of hospitals. For example, 80.5% of all myocardial perfusion scans are performed by the 20% of hospitals doing 18 or more scans per month. Conversely, only 4.4% of scans are done by the 19.6% of hospitals performing fewer than 5 per month. The data do not allow us to speculate about the quality of scans nor the expertise of physicians in either high or low volume hospitals. Indeed, the same physicians may perform these tests in several different hospitals in the same area.

One limitation of our study is that we could not assess availability of echocardiography in physicians' offices. While both scintigraphy and echocardiography require highly specialized technologic equipment and experts to perform them and interpret their results, echocardiography can be performed by virtually any cardiologist who has received proper training. Furthermore, echocardiographic equipment is relatively self-contained, portable and less expensive to purchase than the equipment required for scintigraphy. Finally, scintigraphy may be ordered by a family practitioner, internist, or cardiologist, but must be performed and interpreted by a radiologist or nuclear medicine specialist, usually in a hospital setting. Echocardiography on the other hand, may be ordered, performed, and interpreted by the same physician (e.g., cardiologist). In the fee-for-service sector, there may be financial incentives for physicians to purchase echocardiographic equipment for use in their offices rather than in the local hospital (*17*). This may be particularly true for M-mode echocardiography. Purchased independently, the M-mode equipment is much less costly than 2-D real-time instrumentation. This may account for its popularity among cardiologists performing office-based procedures, where equipment purchasing costs are very important (*2*).

These differences may have caused bias in our findings about the volume of tests performed in hospitals. The number of echocardiograms reported by the hospitals in our survey may only account for a fraction of the number actually performed in the U.S. each year. However, due to their expense and bulk, there are probably far fewer scintigraphic scanners outside of hospitals, so the number of scintigrams reported here may more accurately represent the total.

A second limitation of our data is that they reflect the national utilization patterns as of 1983. However, except for reports of equipment sales by specific manufacturers or regional marketing surveys, the recent

literature does not provide such data elsewhere. Furthermore, our data represent a validation of Pozen's estimates (*5*).

Finally, another limitation is posed by the sampling strategy of asking hospitals to estimate the number of procedures performed only for the (summer) month preceding their reply to the questionnaire. Clearly, seasonal variations may occur in the number of procedures performed.

In summary, noninvasive cardiac imaging by scintigraphy and echocardiography has grown rapidly over the past 15 years. Because cardiac disease continues to be so prevalent in the population, these tests which allow noninvasive assessment of cardiac function will continue to play an important role in clinical medicine. At the same time, both scintigraphy and echocardiography have undergone and will continue to undergo technological improvements. New equipment will allow better resolution of images and new techniques will allow better quantitation and analysis of test results (*2*). New tests may also be developed (e.g., dipyridamole-^{201}Tl scans, exercise echocardiography, digital subtraction angiography, and computed tomographic cardiac cineangiography). Finally, new hospital reimbursement policies may change the picture considerably; prospective reimbursement may restrain technological advances and may curb many hospitals' spending on such medical equipment (*18*).

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