AJR Technology Forum

CT in Your Clinical Practice

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Robert J. Stanley, MD
Editor in Chief

The *American Journal of Roentgenology (AJR)* is widely recognized as a practical journal providing its readers with clinical information that affects their practice. In the rapidly evolving field of radiology, the journal continues to highlight research that illustrates the value of new technologies and procedures.

The *AJR* Technology Forum showcases specific techniques, equipment and procedures that are changing radiology practice. This new feature will include ideas and opinions about how innovation is affecting your practice and patient care.

The *AJR* Technology Forum "CT In Your Clinical Practice" is the first of a series of supplements to the journal. This supplement is based on a survey that was conducted for the American Roentgen Ray Society in conjunction with Philips Medical Systems. The survey results provide a broad outline of the current and future use of CT in clinical practice. Comments by experts in CT put the results into perspective.

The *AJR* has a long history of serving as a forum for debate and criticism in clinical radiology. We hope that the *AJR* Technology Forum will continue that tradition with content that may elicit differing opinions. Readers are encouraged to send letters to the editor of *AJR* commenting on the topic as well as the supplement format.

AJR Technology Forum
CT in Your Clinical Practice

Abstract

This report presents the results of a survey of 500 U.S.-based radiologists on critical issues associated with the use of CT. The survey represents a collaboration between the American Roentgen Ray Society (ARRS) and Philips Medical Systems. An outside firm, ICR/International Communications Research, conducted the survey. Survey questions were designed to elicit opinions about the past, present and future of CT, especially MDCT imaging, in various practice environments.

Most radiologists (69%) indicated that CT has had a major influence on their specialty, more than any other medical advance, and that they expected this influence to increase. The idea that MDCT radically improves diagnostic quality was not universal, and opinions were mixed about the expansion of CT into new applications such as cardiac imaging. A number of concerns were attributed to the advent of MDCT and expansion in the number of slices—a phenomenon commonly referred to as a "slice war." These concerns revolved around managing the data explosion, excessive patient irradiation, bottlenecks in patient throughput, the ability of CT staffs to keep up with the rapidly evolving technology and the costs of keeping up with these changes. Nevertheless, most radiologists (78%) who were surveyed indicated that they used MDCT and that MDCT has had a positive effect on their practices in the past five years (90%); most (77%) expected that the number of slices would increase by two to 10 times the current level. Fifty-six percent said that they would be adding one to two scanners to their practices in the next five years.

Introduction

CT—particularly MDCT—has had a profound effect on the field of radiology, and its continuing evolution influences diagnosis in many other areas of medicine. The almost exponential expansion in CT technology carries with it significant diagnostic potential—particularly in new CT applications. However, there are factors inherent in MDCT imaging that could make this new technology self-limiting. For example, the volume of data acquisition capable with MDCT is unprecedented and has the potential to overwhelm data management and information technology systems in many radiology practices. Moreover, the exceptional speed and efficiency of MDCT will likely tax the current patient throughput systems just as the growing CT system complexity will create a greater demand for staff training, updating and expansion. Finally, the cost associated with staying on top of the ever-shortening cycle of new technology releases, as well as the normal equipment replacement cycle, must also be considered.

This study queried radiologists regarding their perspectives on the changes that CT has brought and will bring to their practices. The results of the survey follow, along with commentary on the significance of these results by distinguished leaders in radiology and selected Philips Medical Systems staff members.

Survey Sample and Methodology

ICR of Media, PA, conducted qualitative interviews and a Web-based quantitative survey to solicit the opinions of radiologists nationwide regarding the current and future use of CT.

Qualitative Interviews

Seven members of ARRS participated in one-on-one, in-depth telephone interviews conducted by ICR. These qualitative surveys followed a discussion guide developed by ARRS, Philips and ICR. The discussions were designed to last 25–30 minutes. However, a number of the radiologists extended their discussions to over 40 minutes. ICR then wrote a summary report on the qualitative interviews, making key recommendations for the content and structure of the quantitative survey that was administered through the Internet.

Quantitative Sampling Methodology

ICR mailed invitations, using letterhead with both the ARRS and Philips logos, to randomly selected ARRS members, inviting them to participate in a Web-based survey. To guarantee a sufficient response, ICR initially mailed 3,000 invitations on November 7, 2003. By November 12, 241 questionnaires had been completed through the Web interface. Seeking a total of 500 respondents, while working with a survey closure date of no later than November 19, ICR mailed 1,500 additional invitations on November 12 and obtained 500 completed surveys by the morning of November 17. Any surveys attempted after the 500 had been received were declined. Five hundred responses allowed for a margin of error of ± 4.4% at the 95% confidence level.

Screening Requirements

A responding radiologist had only to be experienced in the usage, maintenance or purchase of either single-detector CT or MDCT equipment. Individuals who did not thus qualify for the survey were automatically directed to an exit screen. Only seven screened participants did not qualify for the Web survey.

Respondents' Demographics

More than 92% of the addresses on the ARRS-provided mailing list were in the U.S. and Canada. The remaining overseas

Authors: Gregory J. Kohs, MA, is Vice President of ICR/International Communications Research
Joel Legunn, BS, is President of Legunn Communications

Fig. 1. Map shows geographic distribution of the 500 radiologists who responded to the survey.

addresses did not contain a country identifier and, considering the delays in overseas mailing with regard to the survey timeline, the decision was made to mail only to U.S. and Canadian members. Ultimately, the 500 completed surveys were from radiologists based in the U.S. (Fig. 1). Of these, approximately 50% have been in practice for five to 14 years. Sixty-five percent of the radiologists have been in practice for 10 years or more, whereas 35% have been in practice less than 10 years. A little more than a quarter of those surveyed (27%) have been in practice for 20 years or more. Thus, the survey included more long-term than newer radiologists.

A greater percentage of radiologists reported being experienced or dedicated in general radiology, ultrasound and in areas such as abdominal imaging (Table 1). Twenty-three percent or fewer of those surveyed rated themselves as experienced or dedicated in more specialized areas such as neuroradiology. Few were experienced or dedicated in pediatric imaging (6%) or emerging areas including cardiac imaging (4%) and interventional neuroradiology (3%).

Commentary Participants

Commentary on various aspects of the survey were obtained through conversations with Richard Baron, MD*, chair, department of radiology, University of Chicago, Chicago, IL; Bruce McClennan, MD*, past chair, department of radiology, Yale University Medical School, New Haven, CT; James Thrall, MD*, chair, department of radiology, Massachusetts General Hospital, Boston, MA; Jim Green, senior vice president, Philips Medical Systems, general manager, CT Business Unit; Jim Fulton, vice president of global marketing, CT, Philips Medical Systems; and Thomas van Elzakker, MSc., marketing director, CT Radiology Products, Philips Medical Systems, all located in Cleveland, OH.

CT Usage

Single-Detector CT Versus MDCT Scanners

In 2003, 78% (390 of 500) of the radiologists predominantly used MDCT scanners. About one third (33%) used scanners with up to four detectors, 16% used scanners with up to eight detectors and 29% used scanners with up to 16 detectors (Fig. 2). Nearly a quarter (22%) predominantly used single-detector scanners.

Commentary

van Elzakker:

It is not unexpected that about a fifth of the radiologists surveyed are still using single-detector CT. The replacement cycle is approximately six to seven years, and MDCT—especially four to 16 slices and above—has only been around for four to five years.

Baron:

Smaller practices may be slower to move to MDCT because of budget issues—that is, no funding to buy new scanners. It took time for axial scanners to be replaced by helical scanners.

*Drs. Baron, McClennan, and Thrall have indicated that they have no financial relationship with Philips Medical Systems.

Table 1. Respondents' Area of Expertise

Area of Expertise	Percentages of Respondents Who Indicated Experienced or Dedicated in this Area
General Radiology	45
Abdominal Imaging	45
Ultrasound	32
Emergency Radiology	29
Musculoskeletal Imaging	27
Mammography	23
Pulmonary Imaging	22
Neuroradiology	22
Women's Imaging	19
Vascular/Interventional Radiology	15
Pediatric Radiology	6
Cardiac Imaging	4
Interventional Neuroradiology	3
Radiation Oncology	3

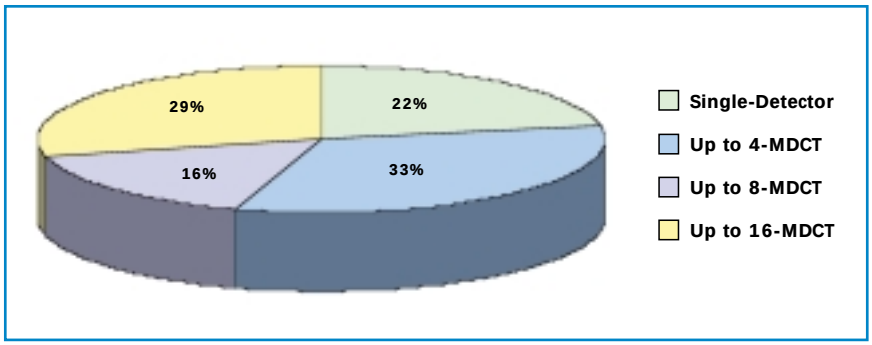

Fig. 2. Chart shows respondents' use of single-detector CT versus MDCT scanners.

For many indications the type of scanner does not matter, but trying to image liver tumors, for example, with single-detector CT is inadequate. For some indications, such as in cardiovascular scanning, using single-detector CT is doing "bad medicine." Everyone should eventually implement MDCT technology, but the changeover is a matter of economics.

Film Versus Filmless Viewing

Eighty-two percent of radiologists view CT images with a workstation/console some of the time (Fig. 3). Nearly half of radiologists view CT images using film some of the time with single-detector users more likely to use film for viewing images. Overlap in these percentages occurs because many use both.

Commentary

Baron:

The technology is reaching a point at which radiologists will no longer be able to interpret MDCT scans with film, because they are bringing in a volume acquisition with possibly thousands of images. Although they can have the technologists select certain images to view, radiologists still have to interpret them on a workstation where they have the ability to see coronal, multiplanar and volume images. Filmless viewing is the only way to interpret MDCT data because it allows manipulation of an image to get at target areas.

Our institution is predominately filmless. However, we still use film for mammography and when scoliosis examinations are performed. The new scanners allow isotropic voxel reconstruction in any plane or in curved reformatted planes, which requires the use of workstations, so why print film as well? There are, of course, many challenges. Getting 100% of all referring physicians to come on board is difficult even though it is truly a step forward for them. Also, backup procedures for unexpected down time or problems require maintaining a secondary image distribution system.

Thrall:

With film, you are limited to specific window settings and may have to change these settings and print multiple copies for different studies. In our institution, radiologists realized the value of filmless interpretation within one day after installation of a picture archiving and communications system (PACS).

Although they may be using filmless viewing, many departments do not have expertise with image postprocessing—3D imaging—which poses a major problem. In our radiology department, we have a 3D postprocessing laboratory with five to six full-time technicians doing nothing but postprocessing and helping analyze sophisticated studies. We are completely filmless for new examinations. We still receive films from outside, though, and some prior examinations are still on film. However, being filmless is the only practical approach for MDCT. It is both physically and financially impractical to print all the images from MDCT examinations, and it is logistically impossible to view high-image-count MDCT examinations using film.

The biggest challenge for us originally in going filmless for CT nine years ago was convincing people that image quality was good enough on the workstations and that they did not need to have eight films of 20 images each displayed at a time. The epiphany was recognizing the superiority of "stack" mode viewing versus multi-image displays. Once people learned to use the stack mode, which took about one week, the game was over. Some clinicians still prefer film, and we have chosen to accommodate them but do not require that they return the images.

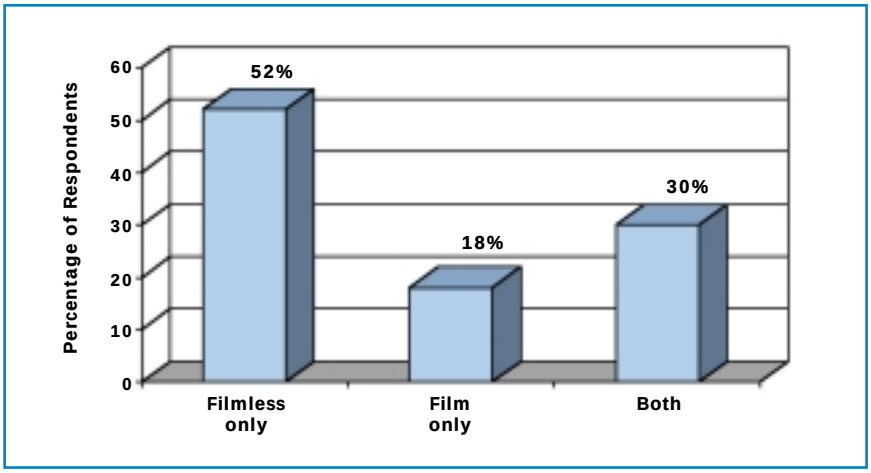

Fig. 3. Bar chart shows percentages of respondents who view soft-copy, hard-copy or both for CT interpretations.

The Use of PACS

The survey found that 64% of radiologists use PACS. This finding was associated with users of higher-detector (16-MDCT) scanners, as well as among those who have more CT units in a practice.

Effects of CT on Radiology

More than two thirds (69%) of those surveyed said that CT had improved their specialty more than most other advances, whereas 30% considered that the improvement was equal to that of other medical advances (Fig. 4). Only 1% thought that the improvements associated with CT were less than those achieved through other advances. The most positive responses regarding CT-associated improvements came from radiologists in practice longer.

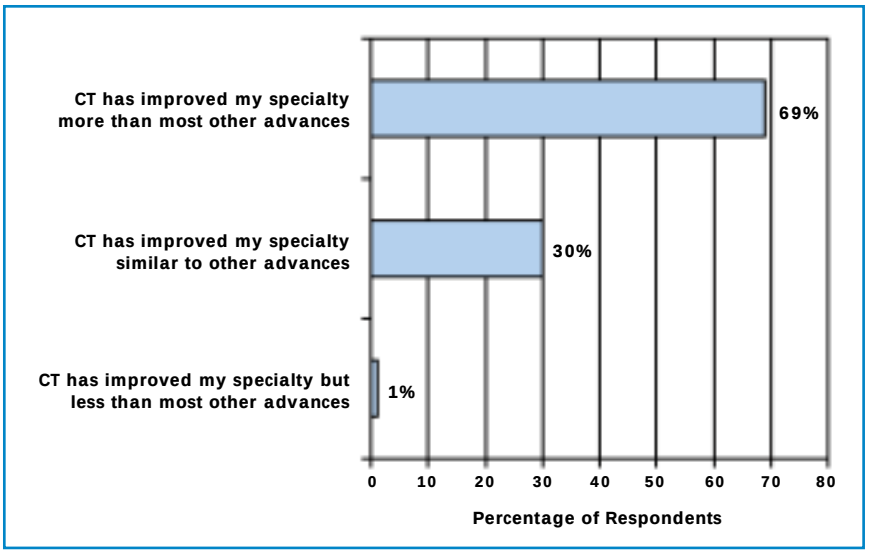

Fig. 4. Bar chart shows degree of improvement respondents believe CT has had on their specialty.

Commentary

Baron:

Before CT, we spent an inordinate amount of time doing diagnostic studies that had a low yield, despite the presence of sizeable disease. Diagnostic quality has increased dramatically with the advent of CT. With CT, we can look directly into the heart of the matter and can participate more effectively in patient care. In our medical center in the cardiac arena, fewer invasive procedures are performed. Our 16- and 40-slice scanners have outperformed cardiac angiography in some cases.

In addition, a CT examination used to take 45 minutes and the scanner cost $1 million. Fifteen years later, the scanner still costs about $1 million, but the examination now takes 15 seconds to three minutes.

Green:

CT gives the greatest amount of diagnostic information to the radiologist in the most consistent format and in the quickest time frame. Its impact on radiology is due to the ability of MDCT to easily enter the workflow of the radiology department, including its connection to PACS.

McClennan:

CT has almost become a fundamental part of diagnosis for a variety of disease states, and it will continue to affect the field of radiology. There is one caveat, however. In some cases this seemingly innocent procedure may be overused, possibly exposing patients to excessive irradiation.

Thrall:

I recall a survey of internists (50 years of age and older) that asked what medical technology changed their practices the most—CT and MRI were the top two. The greatest impact of CT lies in the remarkable gains the technology has yielded in diagnostic specificity and sensitivity.

MDCT angiography has replaced 70–90% of conventional angiography. We almost do not have to perform cerebral angiography for diagnostic purposes anymore. A combined CT angiography/CT scan with 3D reconstructions has also now replaced a CT scan, an IV pyelogram and an angiogram for our kidney and liver transplant patients and has given the surgeons more information than ever before. For example, we can show the surgeon the liver segments and the detailed arterial and venous anatomy as a road map to their surgery in living related donors. MDCT also facilitates functional CT that is used in stroke diagnosis. It is faster and easier than MRI.

Effect of Advances in CT on Practice

When asked to rate the changes in their practices brought about by advances in CT equipment over the past five years, most of the survey participants (90%) agreed that the developments have had positive effects. The respondents stated that the major positive effects are in the areas of increased usage of CT and in diagnosis, followed by speed and quality of imaging and resolution (Table 2). The 11% of radiologists claiming negative effects in their practices pointed to the longer hours involved in the use of CT as a major negative effect.

Commentary

Fulton:

Unquestionably, CT has had a positive impact on radiology practice. This effect is clearly the result of dramatic new applications, better diagnostic quality, better algorithms to review data and the greater comfort

afforded patients because modern scanning is so fast.

Radiologists who believe that the new technology has resulted in longer hours may be reacting to the fact that more patients are now referred for CT than can be scanned in a normal day. Also, so much more data can be extracted from an examination (maybe as much as 2,000 slices compared with 30–40 before) so reviewing the results takes considerably longer.

Green:

The positive effects associated with the advances in CT over the past five years derive from better data storage, flexibility in and expansion of procedures, speed of data acquisition and improved workflow. The reason that some radiologists see the advances in CT increasing their usage time is that, until recently, workstations required for manipulating large data sets have been cumbersome and time-consuming to use. In addition, the lack of standards for data set reduction and storage has left many in a quandary.

Thrall:

The advances in CT have put it on a critical pathway for more diseases and conditions. It is no longer ancillary, but central to the acute care process. Imaging in general is the guiding hand of medicine, and CT in a hospital is the undisputed winner in terms of the number of diagnostic procedures being done.

In fact, it is usual for anyone coming to an emergency room now with major trauma or chest or abdominal pain to have a CT scan. For example, the false-positive rate for the diagnosis of appendicitis was unchanged at 25% ± 5% for 100 years before CT methods were developed. Now, in good hands, the percentage of false-positives is under 3%. The physical examination of the abdomen was never very good, lacking in any kind of specificity for patients with abdominal pain. Now we get the answer with CT. People who need operations are taken promptly to the operating room. People with inconsequential problems are released from the hospital. Fewer patients are held for observation, and fewer unnecessary surgeries are performed.

Effect of CT on Competitiveness, Productivity and Diagnostic Accuracy

Slightly more than one third (36%) of the respondents indicated that MDCT had an effect on the competitiveness of their practices, with about 17% stating that the technology gave them the sense of being more competitive. About 22% of radiologists did not think that MDCT technology had any effect on the competitiveness of their practices.

About 29% stated that MDCT provides them with "increased productivity and speed," specifically saying that it yields "faster scanning" and "increased throughput of patients," with about one in 10 mentioning each of these aspects of productivity.

About 30% of radiologists considered MDCT to have a substantial effect on diagnostic quality, alluding to better imaging, higher resolution, and the capability of 3D construction as important factors affecting quality. The perception that MDCT affords improvements in diagnostic quality was more prevalent among younger radiologists who participated in the survey.

Commentary

McClennan:

The statistic on diagnostic quality signals a need to show the radiology community how the new technology actually affects diagnosis. Radiologists and specialists from industry need to present courses at local society meetings to update the radiology community on the capabilities of MDCT.

Thrall:

Functionally, you do not need all the power inherent in MDCT scanners in every case, but benefits from MDCT technology can be derived in a significant percentage of cases. Many departments have a spectrum of technologies—such as single-detector CT and 4-MDCT scanners. With multiple scanners, the patient can be triaged to the level of technology needed. That means that many radiologists do not always have the opportunity to observe the full diagnostic capability of higher-level MDCT scanners.

van Elzakker:

The quality of MDCT becomes apparent mostly with high-end procedures or studies. Cardiac imaging, for example, cannot be done on single-detector CT or even 4-MDCT scanners. These types of studies are a limited subset of all studies performed. In routine studies the greatest benefit gained from using MDCT is speed of acquisition.

Table 2. Effect of Advances in CT on Practice over the Past Five Years

Most Important Effect	Percentage of Respondents
POSITIVE (net)	90
• Usage	28
• Diagnosis	24
• Speed	19
• Imaging/Resolution	16
• Applications	11
NEGATIVE (net)	11
• Longer Hours	7
• Abuse	2

The Future of CT

Projections for CT Purchases Within a Practice

More than half (56%) of the radiologists surveyed stated that they plan to increase the number of CT scanners in their practices by one to two scanners during the next five years (Fig. 5). Only 1% said they would actually reduce the number of scanners now in their practices, and about one quarter saw no change taking place over the next five years.

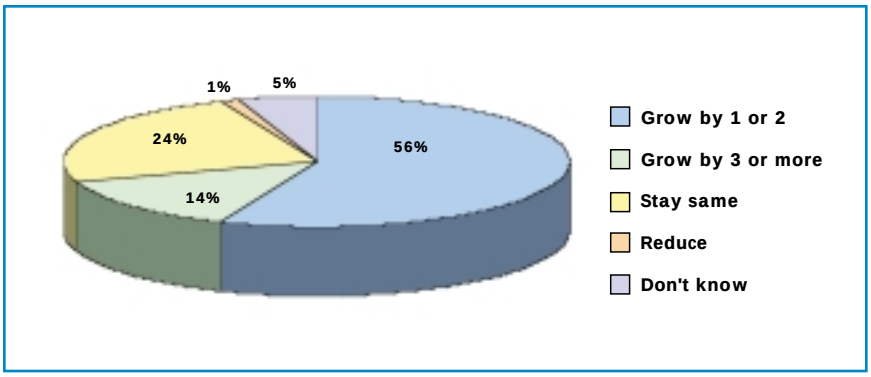

Fig. 5. Chart shows respondents' projections for CT purchases within their practices over the next five years.

Commentary

van Elzakker:

If more than half of radiologists add one to two scanners as indicated on the survey, that would translate into a much higher market growth over the next three to five years than what Philips currently forecasts. I do not believe that radiologists will actually add systems to their practices in such large quantities. One major issue is that there are just not enough technologists to operate these scanners. So, people may plan to add CT scanners to their practice, but they will not have the technical resources to operate them.

Allocation of Financial Resources for CT in a Practice

Budgetary concerns will be a major factor affecting the future expansion of CT into individual practices. In this regard, 46% of the survey group believe that CT will receive a somewhat larger allocation of financial resources in their practices over time—with an additional 2% believing that the allocation will be far larger (Fig. 6). In contrast, 43% thought that the allocation percentage would not change substantially. Any increase, as predicted by the participants, might come at the expense of other diagnostic products, owing to the competition for relatively fixed capital budgets.

Commentary

Fulton:

A look at the CT market going back about eight years reveals that the most powerful products cost between $1 million and $1.2 million. For roughly the same price, a lot more diagnostic power is available now. So budgets in a practice can remain relatively the same with regard to CT scanner purchases, and yet the practice will still be able to obtain a higher level of technology. However, if some new development was absolutely revolutionary, then CT scanners may cost more.

Thrall:

The allocation of greater dollar resources for additional CT units is already a reality and will continue at our institution. We will buy fewer angiography units and fewer X-ray units, but more CT scanners. Because our patient volume for CT has probably doubled in the last five years we are going to invest more in CT and hire more technologists to operate the scanners.

van Elzakker:

As the technique becomes more versatile, CT will probably warrant a larger segment of the capital budget in specific situations. This change will be especially true in emergency rooms and trauma centers, where CT units are replacing radiography units and other first-line imaging devices.

Allocation of Financial Resources for CT in the Field of Radiology

With regard to the future of CT in the entire field of radiology—as opposed to individual practices—the opinions of the group were more divergent. That is, as many as 53% of the participants thought that CT will get a somewhat larger proportion of financial resources in radiology in general, and an additional 4% thought that it would be far larger (Fig. 7). Only 34% thought that there would be relatively little change in budgets for CT in the radiology field, and 8% thought that it would be somewhat smaller.

Commentary

Fulton:

It is likely that there will be an increase in allocation of funds throughout radiology CT in the future, and this will be driven by studies demonstrating that CT can replace a number of conventional, perhaps more invasive, diagnostic procedures now

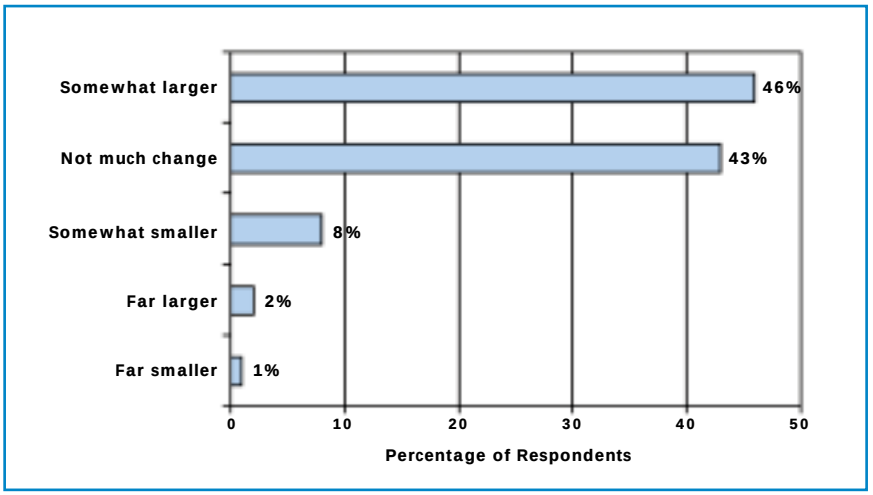

Fig. 6. Bar chart shows how respondents view financial resources for CT in a practice changing over time.

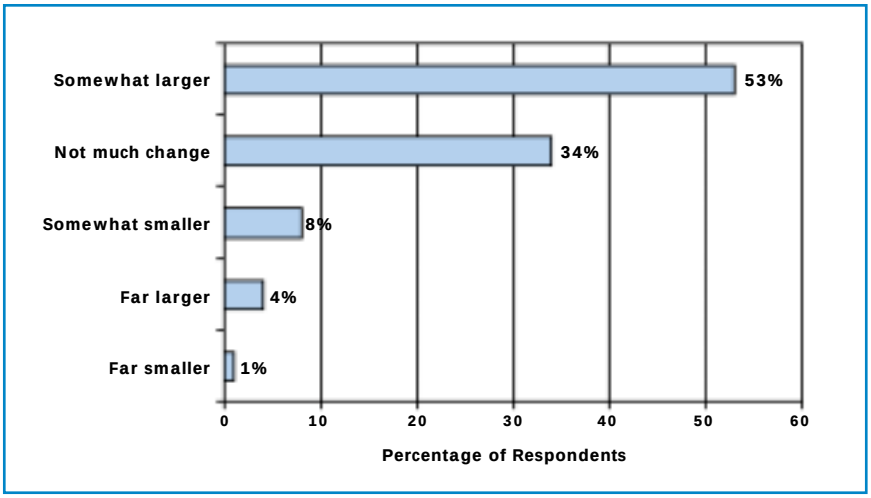

Fig. 7. Bar chart shows respondents' view of future allocation of financial resources for CT in the field of radiology.

in use. For example, if we prove that CT cardiac imaging can replace a coronary arteriogram, there could be more demand that requires a practice to add an additional CT unit.

van Elzakker:

CT purchases will be limited by the inability to provide adequate staffing and other resources, such as space. The replacement cycle will shorten, and institutions will buy faster new high-end scanners. Driven by the fact that MDCT is more usable than single-detector CT, more people will be buying scanners in the $1 million range as opposed to the less expensive units.

Factors Warranting Increased Spending for CT

Those radiologists who believed there should be more funds assigned to CT were asked to pinpoint the factors that would justify such a budgetary increase. The largest response (43%) cited the cost efficiency that would be gained by increasing the availability of CT. Improvement in diagnosis was not a factor cited by most radiologists, and none mentioned the value of CT in the emergency room (Table 3).

The Expansion of MDCT

With regard to the expansion of MDCT technology, most (57%) predicted that the number of detectors in a single scanner would increase two to four times in the next five years—that is, to a range of 16 to 64 slices (Fig. 8). Only about a fifth saw the expansion being five or 10 times the current level, with still fewer believing that the increase would be 10-fold or greater.

These figures may indicate that many radiologists are unaware of the speed with which innovation in CT design is progressing. Current trends suggest that the industry will be well beyond this range in five years. Essentially, a "slice war" is driving the industry at this time. These relatively conservative figures may reflect a desire on the part of radiologists for a greater focus on new applications, increased ease of use, better data management and dose reduction.

Commentary

Fulton:

As we increase the number of channels in a detector, the detector becomes more expensive to build. If you go much beyond 64 slices with the existing technology today, the cost to build a CT unit will increase exponentially, unless some new technology can circumvent the expense.

There absolutely is a slice war. However, rather than focusing on more slices, manufacturers should concentrate their efforts on clinical applications and on providing better data analysis for clearer diagnosis—perhaps

Table 3. Major Factors Cited as a Reason to Campaign for More CT Dollars

Factor	Response (%)*
Cost Efficacy	43
• Reduces need for more expensive/invasive procedures	13
• Increases patient throughput	8
• Generates income/is a profit center	6
• New applications bring in new business/increase revenue	5
Productivity	33
• Faster/increased throughput	11
• Faster diagnosis/turnaround	7
• Faster scanning	6
• Improved patient throughput	4
Effectiveness	30
• Replaces invasive studies/is less invasive	11
• Decreases hospitalization time/time in emergency department	5
• Has better resolution/imaging	4
Improved Diagnosis	16
• Improves diagnostic capabilities	7
• Provides more accurate diagnosis	6
Applications	13
Patient Benefit	8
Demand	7

*Percentages in subcategories do not equal the total for the category because not all radiologists responding to each category gave responses for all subcategories.

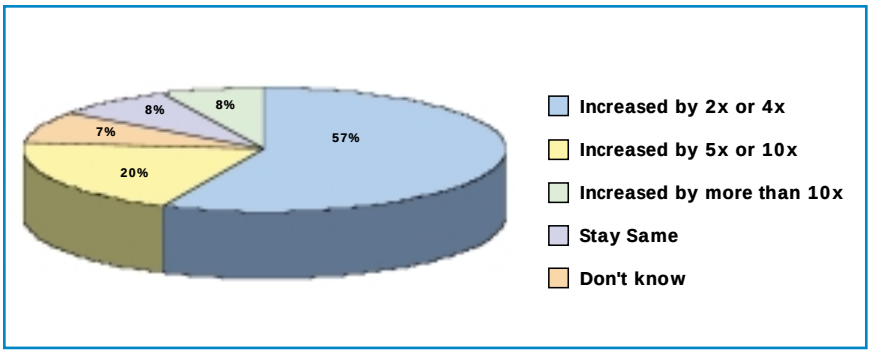

Fig. 8. Chart shows respondents' view of future expansion of MDCT.

with computerized diagnosis that is now in its infancy. In addition, they should direct their efforts toward improving throughput by providing tools that would allow a procedure to be done more efficiently and with a reduction in the radiologist's time.

Thrall:

As the slice race goes on, we have to ask what spatial resolution is needed for certain applications. For example, if you replace the conventional coronary arteriogram with CT, you need to be able to image at a level to see small coronary vessels—down into the submillimeter range, and perhaps down to the 100- to 200-micron range to achieve better diagnostic outcomes. The other aspect of the race involves how much of the body you can image in one revolution of the gantry. We have to stop considering slices for the sake of slices, but focus on what the desired functional outcomes are with one revolution—among them, finer details and the ability to image an entire organ. Ultimately, scanners may be built big enough to do a single-revolution study of the brain or the heart. If you can image an entire organ in one revolution, you can then do functional CT, which is similar to functional MRI—that is, blood flow and perfusion studies can be done for assessment of stroke and other diseases.

Procedures that May Be Replaced by CT

One important factor in the future of CT is the degree to which CT as a diagnostic technique can replace other, more invasive diagnostic procedures. Aortography led the list of procedures that the participants (79%) thought were likely to be replaced by CT (Table 4). CT has already replaced many aortographic procedures.

Only 34% think that CT colonography (virtual colonoscopy) will replace conventional colonoscopy. Only 31% think that CT will replace coronary arteriography, and still fewer (9%) think that it will replace cardiac catheterization.

Commentary

Green:

In time, CT could replace coronary angiography. For timing reasons, stroke assessment may eventually be more effective with CT. All of these changes will reduce the inherent risks in conventional arteriographic procedures.

Thrall:

There is skepticism regarding new applications among radiologists because they do not have much experience with them. Currently, many CT applications that could replace cardiac arteriography and catheterization are mostly being done on a research basis. We are certainly not going to put the cardiac catheterization laboratory or endoscopy suite out of business, but introducing CT in these areas will change the nature of the patients that they see—that is, the number of screening endoscopic examinations will diminish, but the number of endoscopies to biopsy a known polyp will increase. I think that in the catheterization laboratory the concept of the diagnostic coronary arteriogram will be history in three to five years. Therapeutic catheterization is another matter entirely.

Table 4. Procedures That May be Replaced by CT

Procedure	Percentage of Respondents Who Agreed
Aortography	79
Excretory Urography/IV Pyelography	73
Cerebral Arteriography	43
Colonoscopy	34
Coronary Arteriography	31
Cardiac Catheterization	9

Prospects for Patient Procedural Volume

A somewhat larger increase in the number of patients undergoing CT procedures within a practice was expected by 73% of respondents, with another 15% stating that they expected patient procedural volume to be far larger (Fig. 9). Consequently, these radiologists claim that they would like to improve patient throughput to handle the increase. The response was similar when survey respondents were asked about the radiology field as a whole.

Commentary

Thrall:

At Massachusetts General Hospital, we have conducted studies to address the issues of patient throughput and adequate staffing. We developed the concept of "team technology." Historically, a patient would be taken to a CT room, someone would be called in to start an IV and then the patient would be told about the procedure. The scan would be done and images reviewed while the patient

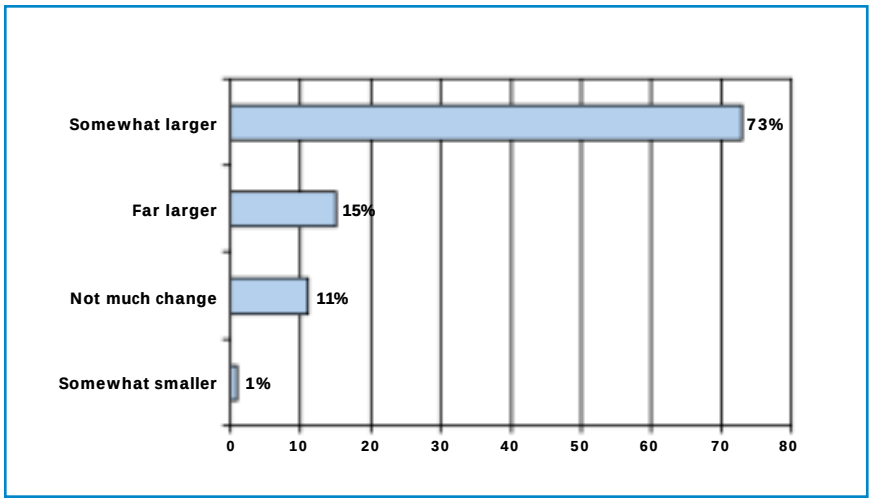

Fig. 9. Bar chart shows respondents' view of patient procedural volume outlook for CT in radiology practice.

was resting in the CT area. We now have a preparation area outside of each CT room. The only thing the CT room is used for is CT scanning. Thus, the throughput is high and efficient and does not result in excess waiting times for the patients.

Essentially, scan suites need new work processes to take advantage of the speed of MDCT technology. All the procedures cannot be done optimally with one technologist per scanner. Hiring a technician assistant is necessary and possibly a nurse to start all the IVs. With such a protocol, the patients are prepared and ready to go when the scanner becomes available. It may be considered as the human equivalent of a parallel processor—some steps can be done at the same time in parallel to each other.

Achieving Greater Patient Throughput

To achieve greater patient throughput, half of the survey participants claimed that they will institute staff changes; 30% said they will increase availability by increasing the technical staff and support. About a tenth of the radiologists (9%) said that they will hire dedicated personnel, IV nurses in particular. Although about 47% will make changes to equipment or apparatus, 20% of those specifically said they will add more equipment such as MDCT scanners and workstations.

Commentary

McClennan:

Because patients can now be scanned so fast, staffing is a major problem. Therefore, we are hiring technician aides who can get patients on and off the scanner quickly, and thus leave the technologist's time free to operate the scanners. We have also initiated new accrediting and education programs for training staff to start the IVs. With these new initiatives, the technologist is free to perform the CT examinations. Because single breath-hold procedures can be done in seconds, the patient throughput time has been decreased considerably. Consequently, there is now more of a bottleneck because patient preparation and handling takes longer than the actual scan time. For this reason, scheduling has also changed, with shorter time slots per patient to accommodate the increased load.

Issues Affecting CT

Radiation Dose and the Data Explosion

When asked to pick the one most significant challenge facing CT in the next five to 10 years, 45% of radiologists chose data management (Fig. 10), especially respondents using 16-MDCT or higher scanners. Radiation dose was also seen as an important challenge (29%), followed by cost concerns (19%).

Commentary

McClennan:

The radiation issue is significant, and even the radiology community is not up-to-date on this topic. Manufacturers should build in controls on CT units that automatically use the lowest radiation dose possible while still delivering a diagnostic study. If required, the technologist would be able to override the automatic controls.

Fulton:

To address the dosage issue, manufacturers must determine how to make CT systems more sensitive without an increase in dose, but there is a trade-off. If there is less dose, there is "less" image.

To handle the data explosion, vendors must work on software tools that allow radiologists to wade through a sea of data without having to assess each slice. But radiologists must adopt a new way of looking at the data, as well. They need to begin thinking in terms of a volume of images rather than a collection of 2,000 slices. Protocols must be developed that allow radiologists to select potential areas of a defect and focus on specific slice ranges.

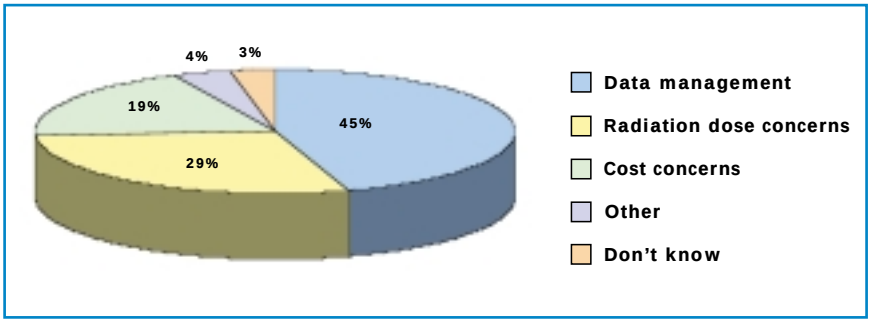

Fig. 10. Chart shows respondents' view of challenges facing CT in the next five to 10 years.

van Elzakker:

To realize the full, long-term potential of CT, vendors must make it easier to work with all the new data. The CT scanner will change from a device that just images anatomy—which it does well—to providing functional studies, and then to the advent of molecular imaging. The latter means that we will be able to inject specific substances into the patient, such as drugs or contrast media with a marker developed for specific tissue types. Then, for instance, we will be able to conduct studies on angiogenesis in certain tumors. We will be able to image not just function but also metabolic events taking place within the organ.

Thrall:

With the advent of MDCT scanners, the number of images per case has gone up from an average of 40 to an average of more than 140, and often much higher. We cannot deal with this overload of data without the use of electronic image management systems, such as PACS.

Dose is an issue because many technologists or radiologists do not have a full understanding of the technology. They may not be aware that there are protocols to reduce patient radiation exposure. Typically, a CT vendor will have nominal recommendations for protocols that are designed to produce good-looking images. In what percentage of cases do we need "pretty" images? A vast majority of departments just use these nominal values given by vendors, which may be unnecessarily high. All vendors have now included automatic current modulators for each channel (detector) to reduce the radiation exposure for areas of the body that are thinner.

We have been concerned about radiation dose and actively involved in research to lower it for more than six years. We have demonstrated in every organ system and for pediatric patients that nominal protocols used historically and coming from nominal vendor recommendations result in higher than necessary radiation doses. We have implemented a broad dose reduction program in the department with many applications at half or less than the historic levels. Nonetheless, we also recognize that the highest unacceptable dose is for someone who should not have been scanned in the first place. To this end we are implementing a decision support system that gives immediate feedback to ordering physicians regarding the appropriateness of performing CT exams for specific clinical indications.

Of course, another challenge is keeping up with the horsepower race. The cycle time between new product releases for major advances in CT was typically a two- to three-year interval, and it was possible to keep up. Now time between advances is down to an 18- to 24-month cycle, which will put a lot of stress on hospitals to stay current with the technology.

In essence, there is no particular value in owning a physical object—that is, a CT scanner. What we need departmentally is a set of capacities rather than owning an object. We should lease rather than own and be allowed to trade in for newer technology that provides state-of-the-art functionality. According to the American Hospital Association, the depreciation cycle for CT scanners is five years; that could dictate the lease term. If 18 months later 64-MDCT scanners are announced, you must still keep your current leased system for another three to four years—that is, unless you can trade it back to the company, a practice that has not been widely worked out yet. One way to accomplish this is to have earlier technology scanners shipped to practice settings where they would be considered "newer" technology and then replace them with the latest technology as part of an "evergreen" lease.

The human resources will be challenged, as well. Learning and adapting to new protocols and keeping people trained at the state-of-the-art level will be a constant challenge. This growth rate is unprecedented in the history of CT, and the solution is not being addressed by manufacturers. They are not structured to provide the training and the asset management programs that institutions are going to want and need.

The Need for Staff Training

The rapid advances in and increasing complexity of CT technology are issues that are constantly encountered by CT staff. Notably, 37% of respondents anticipate that their CT staff will face more operational difficulties with increasing CT complexity, whereas 33% think that their staff will become more capable of handling this complexity, and 28% expect no changes in staff capability as complexity increases.

Commentary

Baron:

New scanners will actually make it easier to acquire more data through better user interfaces on screen and the like, so the technologist's burden should not increase. In addition, we are no longer sending slices. Data will be sent to workstations where they will be interpreted in volume by radiologists. If anything, a somewhat greater burden of complexity will fall on the radiologists who will be interpreting the data, rather than on the technologists involved in acquiring the data.

Fulton:

The number-one issue of MDCT is that there is now newer and significantly more information than ever been before. This increase is going to affect both technologists who acquire the data and radiologists who need the constantly evolving expertise to interpret the data. Manufacturers are now obligated to make a CT system as easy as possible to use without diminishing its high-tech value. They need to be more proactive in training users how to operate the systems—both on-site and in the classroom. A pivotal change in education will be to provide more real-time assistance at workstations via the Internet. It will also be necessary to work with thought leaders at universities to provide in-depth continuing medical education programs, not just one-day tutorials.

Thrall:

Certain CT manufacturers are now taking the initiative to provide advanced training for radiologists and technologists. We are now looking to do the same thing at Massachusetts General Hospital.

Manufacturers are reluctant about appearing to teach or practice medicine, so

they will not go past a certain point in telling customers how to use the equipment. The dilemma here is that most customers do not know how to use the equipment unless someone teaches them. Consequently, very few sites are getting the full value back from their technology purchases. Manufacturers must be more willing to teach radiologists how to use equipment effectively.

We actually have a training unit in our department that works with our technical operations managers and physicians to help implement new technology. We typically flowchart the work process for any new technology and use that as a template for designing an educational program. In brief, we determine for each process step who is involved and what knowledge is necessary to accomplish that step. We use this to craft an educational program for each person involved. The training is documented at the point of completion and further verified by competency-based observation of performance or examination.

van Elzakker:

People need to be trained better, and there is room for product improvement. If you look at the way CT technologists work, there is a stepwise approach for every procedure. What the vendors need to do is to offer only those choices that are applicable for a given situation. This focus would reduce the number of mistakes that can occur and render the system easier to use. This tactic would also reduce the amount of required training. It basically comes down to creating algorithms for different protocols.

Turf Wars

One area that is likely to affect the future expansion of CT is that of competition between radiologists and referring physicians. More than half (54%) of the radiologists surveyed expect some sort of turf battle with physicians whose practices will be adversely affected by the success and advances of CT technology (Fig. 11). An additional 30% think that this clash could be significant. Specifically, many radiologists expect that there will be considerable competition between radiology and other referring specialties. About 10% of the respondents do not anticipate turf battles.

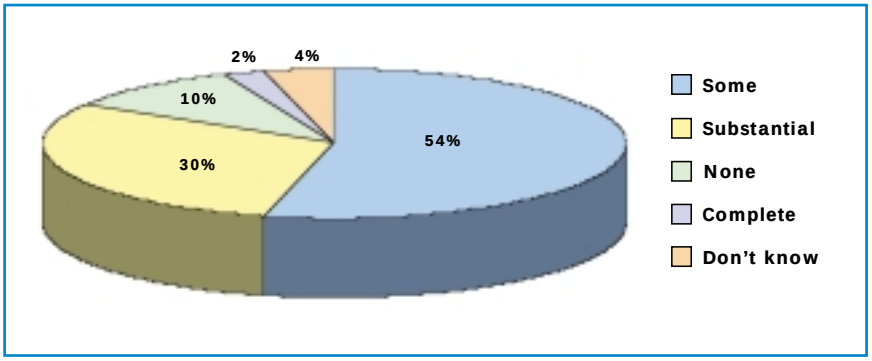

Fig. 11. Chart shows respondents' view of the turf battle with referring physicians regarding CT.

Commentary

Thrall:

Just about every specialty has some work going on at odds with traditional radiology practice. For example, neurologists want to interpret CT head scans.

Cardiologists want to do peripheral vascular angioplasty or take over nuclear cardiology, and their focus on imaging will apply to CT as well. They will seek to replace radiologists. Cardiologists have a demonstrable history of self-referral. About 20% of cardiologists in a group may do imaging. Thus they have a natural internal self-referral system. For example, they often do numerous echocardiography studies recommended by their colleagues. A large cardiology group could buy its own MRI or CT scanner and have enough internal self-referral to make it profitable. Unfortunately, radiologists abandoned the heart about 30 years ago.

In contrast, radiologists have historically been involved with the colon. There are not enough gastroenterologists to process all the people who need screening (colonoscopy) but have not had the procedure. Turf in this setting will be quite different.

van Elzakker:

A radiologist is always in a weak position when dealing with a referring physician because he or she does not control the patient. The clinician determines how that patient will be treated. Radiologists get the patient because there is not enough reason for referring physicians to do the imaging procedure themselves or because they are not equipped, but that is slowly changing. For example, radiologists used to do most of the vascular imaging. Eventually the vascular surgeons took over and started buying their own vascular imaging laboratories. In the turf battle that ensued, the radiologists eventually lost. The same thing may happen with cardiology.

Fulton:

We will continue to see the use of CT expand into other specialties in the hospital—neurology, cardiology, emergency medicine and others. CT will become more than a radiology-based product and will be purchased by other specialties as well.

Referring Physicians' Awareness of CT Benefits

Considering that referring physicians are major gatekeepers for which techniques are used in diagnostic imaging, it is notable that 48% of the respondents said that their referring physicians are not very aware of the benefits associated with MDCT. However, 45% of the respondents thought that their referring physicians are aware of these benefits. If the perceptions of the radiologists are true, such a lack of awareness among almost half of referring physicians about the diagnostic improvements provided by MDCT technology may significantly erode future CT volumes.

Commentary

Baron:

A good number of referring physicians are not aware of what CT can do and may

be ordering the wrong tests. For example, at a recent National Institutes of Health consensus conference on liver disease, many hepatologists were still discussing sonography as the appropriate screening tool for detecting liver tumors in cirrhosis. Apparently these clinicians were not aware of the rapid advances in CT. This lack of awareness needs to be addressed by having radiologists speak more at national nonradiology medical meetings. In addition, we have to broaden the base of radiologists' expertise, as well. Many clinicians come from institutions in which the resident radiologists are not informing them about the value and capabilities of CT, so they are not aware of the advantages of CT.

McClennan:

There has always been a lag between the advent of new technology and radiologists obtaining it, using it and educating their referring physicians about it. MDCT technology is just another manifestation of that normal lag, although the slope of the technological change is a bit steep going from four to 64 slices. The appetite for 3D and reconstructed images among referring physicians is growing rapidly, so their current lack of knowledge regarding new applications should not present a problem to the future expansion of CT into new areas and applications.

Thrall:

It is harder to make people aware of incremental improvements in a technology as opposed to when something revolutionary appears. For instance, CT was such a stunning advance when it became available that everyone knew about it. However, when you go from one slice to four, to 16 and so on, the changes are more subtle. One solution to this communication problem would be for CT manufacturers to distribute literature that discusses the 10 most important attributes of MDCT compared with single-detector CT.

The exceptional changes and capabilities that are appreciated by radiologists may mean nothing to referring physicians. Being able to process twice as many patients in one room (a major productivity gain) is significant to the radiologist but is of no concern to the primary care physician. For referring physicians to appreciate the changes, they must be apprised of the new functional capabilities (applications), but they do not necessarily have to understand the technology to prescribe tests. For example, simply knowing what a new MDCT scanner is capable of would allow referring physicians to exercise a variety of diagnostic options. They can order a CT angiogram rather than a conventional one or a CT colonogram rather than conventional colonoscopy. It would help pediatricians to know that their young patients no longer need sedation, as was necessary with more conventional imaging, because the MDCT scans are so fast.

Conclusion

These data illustrate opportunities and challenges for the future of CT. Most survey respondents agreed that CT has and will continue to have a positive effect on individual practices and the entire field of radiology, citing gains being made in new applications, degree of usage, resolution, speed and diagnosis. The data does, however, point to a need for greater education of referring physicians on the increasing diagnostic utility of CT. There was a call for greater ease of use in future CT systems, because increasing complexity could outpace the capabilities of CT staff. Almost a third (31%) of those surveyed believe that the demand for CT will increase, driven by a greater desire to use noninvasive or less invasive imaging techniques as well as by the increase in the number of elderly individuals in the population. About a fifth (21%) cited efficiency issues as a factor in the trend toward greater use of CT, specifically as it bears on early detection and diagnosis.

The potential of CT to replace other, more invasive diagnostic techniques is great, but turf wars initiated by referring physicians who want to maintain control of their patients remain a challenge. Although most radiologists expect that budgets will be increased over time for CT, many of the respondents (46%) think that reimbursement issues may affect the future of MDCT. Survey respondents indicated concern for the increasing radiation dose exposure with the increase in MDCT capacity, mandating better dosage management. Similarly, there is concern that greater slice capacity will place a heavy demand on data management and processing, possibly creating significant bottlenecks in patient throughput. ■