Practical issues regarding the incorporation of PET into a busy SPECT practice

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Incorporating positron emission tomography (PET) imaging or PET/computed tomographic (PET/CT) imaging into a clinical cardiology practice provides opportunities to better assess patients as well as to expand the services offered by the practice. Clinical evidence continues to accrue, demonstrating the superior quality, the breadth of assessments possible, the diagnostic certainty and accuracy, and the lower patient radiation exposure of PET versus single-photon emission computerized tomography (SPECT) myocardial perfusion imaging (MPI). PET imaging is more accessible to non-hospital imaging centers than ever before because of the availability of radiopharmaceuticals that can be generated on-site or delivered in unit doses from regional cyclotrons, and camera systems of lower cost than previously available. In this manuscript, we offer guidance on the many factors a practice must address before replacing an aging SPECT camera or adding new PET or PET/CT imaging capabilities. Key among these are defining the PET and CT procedures the practice members wish to perform, learning the equipment and radiotracers required to perform those procedures, determining whether their facility has sufficient physical space and shielding to accommodate the dedicated PET or PET/CT instrumentation, and addressing issues related to the practice's referral base, competition, cost-of-entry, reimbursement, and return on investment.

Key Words: PET imaging · SPECT · Myocardial perfusion imaging: PET

INTRODUCTION

Positron emission tomography (PET) myocardial perfusion imaging (MPI) has been available for many years but has been relatively underutilized. This is mainly because few sites had the on-site cyclotron required to produce PET perfusion radiotracers, and because camera hardware and software had not been optimized for routine assessments of MPI. However, the instruments now available offer highly sophisticated acquisition of PET perfusion images with attenuation correction (AC), ECG gating, automated reconstruction, generation of left ventricular function data, and quantification of perfusion. Rubidium-82 (Rb^{82}), which is eluted in a portable generator in the imaging room (thus eliminating the need for an on-site cyclotron), has become the radiopharmaceutical of choice for PET MPI. Key clinical studies have documented the substantially improved quality of PET images that result in greater diagnostic accuracy of PET versus single-photon emission computerized tomography (SPECT).[1] Of great interest, microvascular disease can now be assessed via quantitative measurement of regional and global myocardial blood flow (MBF). All these factors have led a growing number of cardiovascular SPECT laboratories to replace aging SPECT cameras with either line-source PET cameras or hybrid PET camera systems with computed tomography (CT) capability. At a minimum, CT provides AC for PET MPI, while more sophisticated CT systems allow extensive cardiac and non-cardiac anatomical imaging, quantification of coronary calcium, and non-invasive CT angiography (CTA). Once the instrumentation is installed and operational, physicians will find cardiac PET imaging to be extremely useful to them, to their practice, and importantly, to their patients.

Implementing cardiac PET imaging in a busy SPECT practice requires consideration of many different factors, which can be categorized as follows:

- Potential uses of a cardiac PET or PET/CT system
- Equipment choices

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- Facility and space considerations
- Patient selection and referral
- Financial considerations.

Each of these topics is discussed in detail in this article.

Potential Uses of a Cardiac PET or PET/CT System

Acquisition of a PET imaging system allows not only more accurate MPI but also presents opportunities for cardiac imaging beyond the assessment of MPI. The practice must anticipate all uses of the PET system, including, most importantly, whether the camera will be dedicated to cardiac imaging or shared with nuclear medicine/oncology. Generally, the same cardiac PET procedures can be performed with either a line-source or hybrid PET/CT camera, but specific protocols will differ with the two systems. For example, transmission scans are acquired more rapidly with CT than with line-source systems. Table 1 summarizes the PET and PET/CT imaging procedures of greatest interest to a cardiology practice. A hybrid PET/CT system is required for oncology studies.

Table 1. Potential uses of and considerations for cardiac PET systems

Will system be used for cardiac procedures only, or shared with nuclear medicine/oncology?
What cardiac PET procedures are planned?
Myocardial perfusion imaging
Future imaging procedures enabled by new ^{18}F-labeled radiopharmaceuticals
Measurements of absolute and regional MBF
Myocardial viability
Myocardial sarcoid testing
What CT imaging procedures are planned?
None
Calcium scoring, conducted alone or with PET imaging
CT procedures of non-cardiac structures
Coronary CTA
What radiopharmaceuticals will be used?
^{82}Rb
^{18}FDG
$^{13}NH_3$
$H_2^{15}O$
New ^{18}F-labeled agents

PET, Positron emission tomography; *CT*, computed tomography; *^{82}Rb*, rubidium-82; *18F*, fluorine-18; *^{18}FDG*, fluorine-18 fluoro-2-deoxyglucose; *$^{13}NH_3$*, nitrogen-13 ammonia; *$H_2^{15}O$*, oxygen-15 water.

Anticipating which cardiac PET procedures will be performed (such as MPI, myocardial viability, and absolute quantification of MBF) is critical to deciding which system to acquire, as the detector technology, costs, and space requirements may differ considerably. Currently, myocardial viability and myocardial sarcoid activity can be evaluated with a fluorine-18 (^{18}F) imaging agent such as ^{18}F-fluorodeoxyglucose (^{18}FDG).[2,3] Other ^{18}F-labeled agents under development may enable routine MPI.[4] Measurement of global and regional MBF is becoming more widely available and accepted in the clinical arena,[5,6] and a practice's desire to offer this information should be considered when deciding which equipment to buy, since this capability is not standard and is not available on all systems. A key factor that impacts equipment selection, space considerations, staff training, and costs is whether the practice wishes to offer CT procedures such as quantitative calcium scoring, peripheral vascular disease assessment, and coronary CTA. These CT assessments can be done alone or in conjunction with cardiac PET imaging. In general, 4-slice CT scanners allow qualitative calcium scoring; 8 to 16 slice instruments allow CT imaging of non-cardiac structures; and 64 or more slices are required for diagnostic CTA. Thus, if CT procedures are to be implemented, a hybrid CT/PET system is mandatory, and the types of CT procedures contemplated will have an effect on the complexity and cost of the instrumentation.

In summary, a cardiology practice considering the acquisition of PET equipment needs to carefully consider all potential applications. Factors of importance are the type of cardiac PET procedures contemplated, as well as whether non-PET CT procedures will be performed.

EQUIPMENT CHOICES

The first consideration in selecting equipment is whether the PET camera system is an addition to or a replacement for a SPECT camera. If it is a replacement and physical space is an issue, a dedicated line-source PET camera may be preferable since they are generally smaller than PET/CT systems (Figure 1). Adding CT instrumentation increases the size of the system. On the other hand, if space is available and/or if renovation is feasible, then a larger PET/CT camera may be more appropriate to accommodate future growth of the practice. As with SPECT, AC with PET can be accomplished with either a radionuclide line source or CT. But a key difference is that AC is required and fully implemented on all PET camera systems, whereas it is an option in SPECT imaging. PET systems were historically developed with line-source AC; however, with a single exception, no new, dedicated line-source

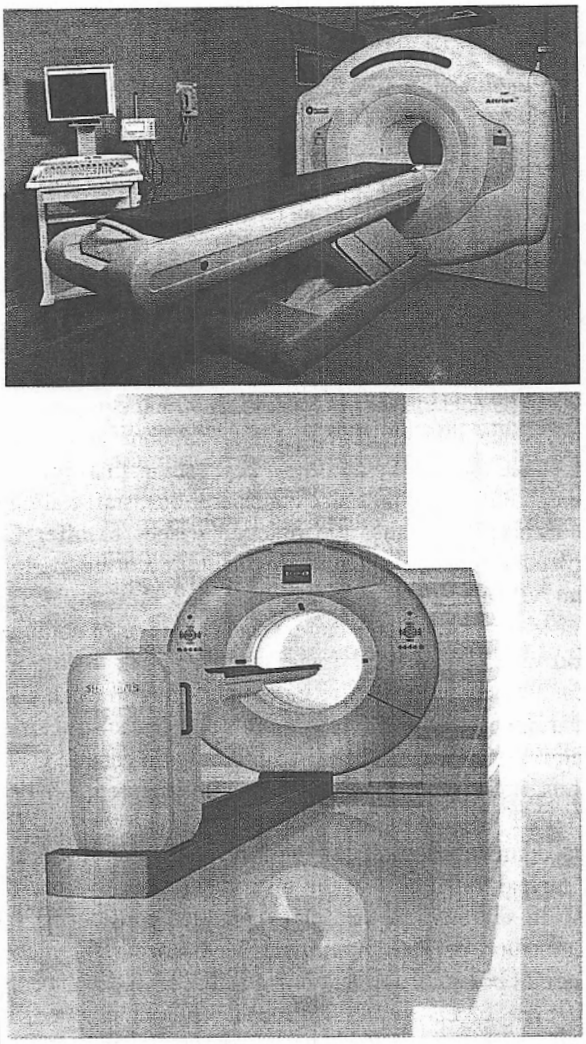

Figure 1. Examples of a PET-only system (*upper* Attrius by Positron) and a PET/CT system (*lower* Biograph mCT by Siemens). *Sources of photos*: *upper* Peter Webner, Positron; *lower* Nicole Webber, Siemens.

PET systems are being produced today. Virtually all the major camera manufacturers have moved to hybrid PET/CT instrumentation. Table 2 outlines some factors that should be considered to select the appropriate PET system.

The myocardial perfusion image quality of line-source PET systems can be excellent. Their advantages over hybrid PET/CT systems are that they are less expensive, they are generally smaller and more amenable to space requirements for SPECT system replacement, and the images can be interpreted without a radiology consultation since there is no CT component. There are also several drawbacks. Because the line-source AC requires a separate acquisition, PET procedures take several minutes longer than hybrid PET/CT systems. The selection of line-source

Table 2. Considerations influencing choice of a cardiac PET camera system

Is the camera system an addition to or a replacement for SPECT?
Space considerations for PET or PET/CT camera system
Line-source versus CT for AC (dedicated vs hybrid systems)
New or refurbished camera system

SPECT, Single-photon emission computed tomography; *PET*, positron emission tomography; *CT*, computed tomography; *AC*, attenuation correction.

cameras will be limited to those sold by the one remaining manufacturer, or to older, refurbished PET systems. Parts and service for refurbished systems are available, but this may become more challenging as the equipment ages. Because CT is not part of the system, those practices desiring use of CT instrumentation beyond AC, such as calcium scoring or other CT procedures, should obviously not consider line-source PET camera systems.

Hybrid PET/CT systems have been available for several years. The strengths of these systems include:

- Shorter overall procedure times, since CT AC is accomplished in seconds (compared to several minutes for radionuclide line-source AC),
- CT images can be used to visualize extracardiac structures and to measure coronary calcium qualitatively and/or quantitatively,
- CTA is possible, providing the practice with an additional clinical capability.

Both new and refurbished systems are available, and manufacturers continually improve both PET and CT hardware and software. There are, however, several drawbacks. Hybrid camera systems are larger and therefore require more facility space, and they are usually more expensive because they include both CT and PET camera elements. Technologists and physicians must know—and be certified in—CT instrumentation in terms of acquisition, processing, and interpretation.[7] When appropriate, practices may request that a consulting radiologist read the study, but compensation for an additional evaluation is separate from interpretation of the PET study. An additional consultation may introduce additional costs, complicate payment, and lengthen the time to generate the final report. In some circumstances, a radiology over-read of cardiac images may be necessary, which may introduce additional costs, complicate payment, and lengthen the time to generate the final report.

FACILITY AND SPACE CONSIDERATIONS

Introduction of PET imaging into an established SPECT practice may involve a relatively simple replacement of the SPECT camera with a small PET system in the same imaging room. Upgrading to a hybrid PET/CT system is somewhat more complicated, as the PET/CT systems are generally larger and heavier than SPECT cameras and typically require a room measuring at least 14 × 24 feet.[8] Specific dimensions of the instruments and space recommendations are available on manufacturers' websites. Most non-hospital practices will likely use ^{82}Rb for PET perfusion imaging because it is eluted on-site from a portable generator and does not require a cyclotron (Figure 2). The radiopharmaceutical, generator, and infusion system are contained in a dedicated cart that requires approximately 4 × 4 feet of floor space. Rubidium-82 and other currently available PET tracers are incompatible with exercise stress imaging because of their short half-lives, and so must be administered during pharmacologically induced stress while patients are positioned in the camera. Therefore, the imaging room must be large enough to accommodate the camera and control area, the technologist, an infusion pump for the pharmacologic stress agent, and the ^{82}Rb generator with its infusion system and storage cart.

Prior to introducing CT capability and higher energy PET tracers, the practice must assess the adequacy of shielding in the imaging room, the control room, and the areas used for ancillary equipment and dose preparation. The amount of shielding required depends on the equipment and anticipated use, the energy and half-lives of the tracers used, and the use of adjacent space.[9,10] For instance, less shielding may be required for the use of ^{82}Rb than for ^{18}F-labeled radiotracers because of the difference in their half-lives.[11] Administration of an ^{18}F-labeled radiopharmaceutical during exercise-induced stress may require a shielded exercise room. A room with two exterior walls requires less shielding than an interior space adjacent to waiting rooms. An example of a PET/CT camera at the corner of a building is shown in Figure 3.

Site radiation officers, independent nuclear medicine consultants, and equipment manufacturers provide professional guidance on facility design and shielding requirements to ensure compliance with Nuclear Regulatory Commission, Food and Drug Administration, and Intersocietal Commission for the Accreditation of Nuclear Medicine Laboratories (ICANL) regulations. Web sites for the regulatory bodies, professional societies (American Society of Nuclear Cardiology [ASNC], Society of Nuclear Medicine [SNM], Radiological

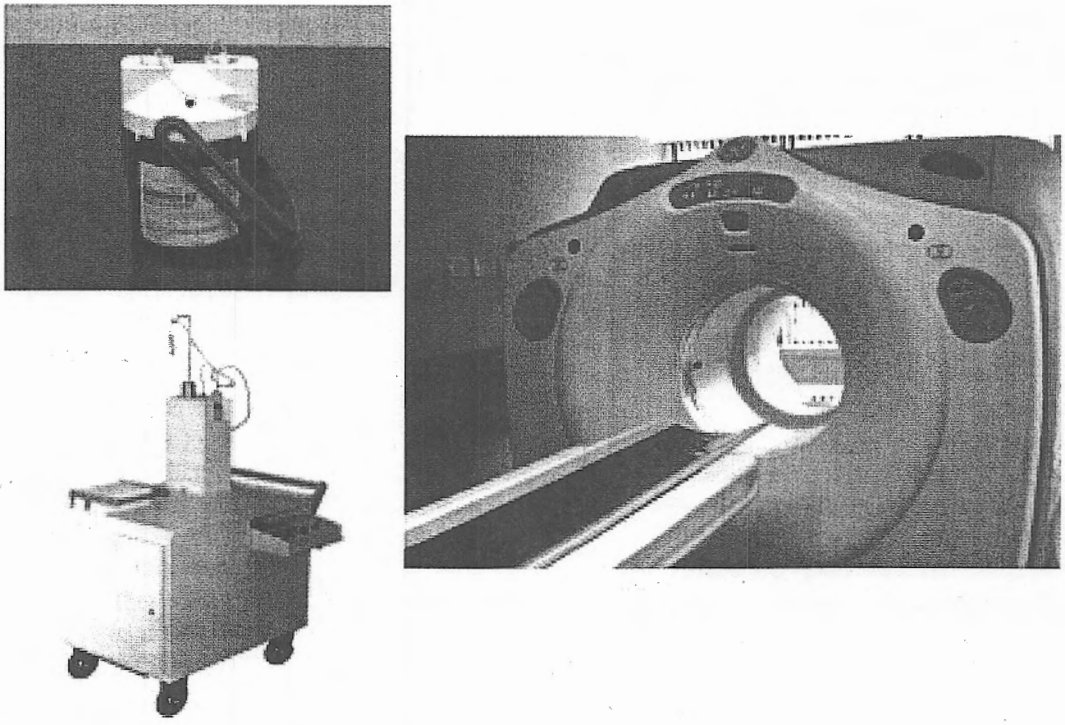

Figure 2. Equipment required for PET perfusion imaging with ^{82}Rb. Clockwise from *upper left*: ^{82}Rb generator; PET/CT camera; ^{82}Rb generator/storage/infusion cart. *Sources of photos*: *left upper* and *lower* Bracco Diagnostics; *right photo* author.

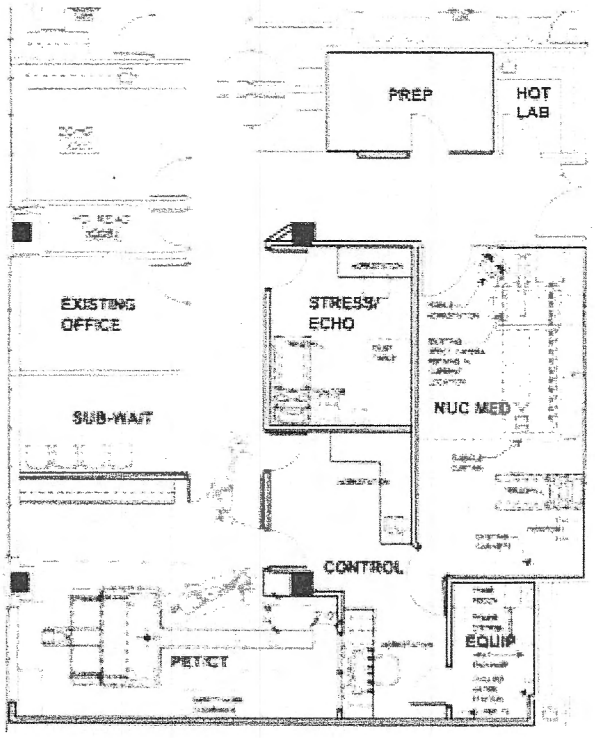

Figure 3. Schematic of a PET/CT camera system located in an outside corner of an office practice. Diagram courtesy of author.

Society of North America [RSNA]), and manufacturers of PET radiopharmaceuticals and equipment may provide specific guidance for facility design requirements, and a wealth of information on all aspects of introducing PET and PET/CT. Annual scientific society meetings offer opportunities for meeting with equipment manufacturers, independent consultants, and purveyors of turn-key PET/CT systems.

PATIENT SELECTION AND REFERRAL

An advantage of SPECT imaging is that referring physicians and payers are familiar with its indications, its data, and with the practical considerations for patient testing. If a practice introduces PET or PET/CT, imaging physicians must consider the factors itemized in Table 3 and educate their referring physician base and payers as to the advantages of this new modality. These advantages include reduced patient dosimetry, higher quality and greater diagnostic certainty, shorter study protocols, additional clinically important information such as left ventricular function at peak exercise, calcium scoring, non-invasive coronary CTA, and assessment of microvascular function through measurement of global and regional quantitative MBF.[1] Thorough and interactive discussions

Table 3. Issues to consider regarding referral base

Physician referral patterns
Will referring physicians specify PET versus SPECT, or will lab personnel decide?
How will referring physicians be educated?
Will PET replace SPECT? How quickly? For which patients?
Carrier approval
Competing sites

SPECT, Single-photon emission computed tomography; *PET*, positron emission tomography.

with referring physicians will enable identification of those patients best suited for a PET or PET/CT scan versus those who would be best suited for a SPECT study. Imaging centers must also facilitate efficient ordering, reporting, and payment.

The joint imaging guidelines issued by the American College of Cardiology, the American Heart Association, and the ASNC have not yet specifically included PET perfusion imaging. However, a recent ASNC statement recommended that PET be considered as the first-line option for patients referred for a myocardial perfusion test when a nuclear perfusion test is indicated.[12] When available, PET MPI is preferred in the following patient types and clinical circumstances: intermediate to high pretest likelihood of coronary disease, concomitant cardiovascular diseases, pharmacologic stress, obesity, or prior equivocal SPECT study. PET perfusion imaging is also preferred in patients with known or suspected diffuse microvascular disease, since absolute MBF can be measured (Table 4). Since SPECT perfusion imaging has been widely utilized for many years, its prognostic and diagnostic benefits have been defined in many patient populations. The growing availability of PET perfusion imaging is only now enabling definition of those patients for whom PET is most appropriate. Because of the short half-lives of the currently available PET radiopharmaceuticals, most comparisons of PET and SPECT perfusion imaging have been made in patients during pharmacologically induced stress.[1,13,14]

Rubidium-82 is well tolerated by patients.[15] Initial studies with flurpiridaz F 18, a myocardial perfusion tracer in development, suggest it may also be associated with few side effects.[16] While some PET perfusion protocols may be shorter than SPECT procedures, all patients must be capable of lying still in the camera for several minutes with their arms raised over their head or kept flat at their sides. Claustrophobia will remain an

Table 4. Patients who may benefit from PET perfusion imaging

Referred for pharmacologic stress
Intermediate to high pre-test likelihood, or known CAD
Obese
Microvascular disease
Equivocal SPECT studies
Need for evaluation of regional, global MBF
Non-perfusion indications
Myocardial viability
Cardiac sarcoid

CAD, Coronary artery disease; *SPECT*, single-photon emission computed tomography.

issue for susceptible patients and may be a greater concern with hybrid PET/CT cameras due to the longer bore of these systems. PET imaging is generally preferred in obese patients because of the higher energy of the tracers and superior AC methodology that PET affords, but very large patients may have trouble fitting into a PET camera.

FINANCIAL CONSIDERATIONS

Practitioners and equipment manufacturers are clearly heading toward a wider adoption of PET and PET/CT imaging. Although the instruments are more costly, they should now be considered when a SPECT camera is approaching the end of its life span or when expansions of imaging suites are considered. Prior to introducing PET into a clinical practice, a comprehensive financial analysis must be performed (Table 5). A practice must determine whether its current patient volume can support the costs of entry, whether patient volume can grow sufficiently to offset the costs, and whether the costs can be shared with other specialties.

The potential income generated by an expanded offering of clinical assessments that were not possible with SPECT imaging (e.g., measurement of absolute blood flow, calculation of coronary flow reserve, myocardial function at peak stress, coronary calcium, and CTA) may readily offset the costs of the new instrumentation, though an important consideration is whether these assessments are indeed reimbursable. Reimbursement for cardiac SPECT procedures is established, while PET reimbursement policies in some regions, especially those where cardiac PET centers do not exist, are still evolving. Payers often treat reimbursement for hospital-based versus office-based imaging centers differently; it would be beneficial to learn whether and how carriers are covering and paying for these procedures in the state,

Table 5. Financial considerations

Cost of camera system (new vs refurbished)
Cost of loss of SPECT reimbursement for patients shifting to PET
Cost of loss of use of imaging suite during equipment switch
Cost to expand or renovate space
Cost to upgrade shielding
Cost of radiopharmaceuticals (unit dose vs generator)
Cost of non-camera equipment (infusion system, generator)
Cost of staff training
Are procedures hospital- or practice-based?
Are carriers reimbursing in the state?
Is anyone else performing procedure in area or state?
Are ICD-9 codes acceptable to help determine who will have a PET study?

ICD-9, International Classification of Diseases, 9th revision; *PET*, positron emission tomography.

and which reimbursement codes are acceptable. SNM, ASNC, and many PET equipment manufacturers maintain updated web site content regarding coding, coverage and payment. In areas or states where PET MPI is minimally available, extra effort may be required initially to educate payers as to the benefits of the procedure. Payers may be particularly interested in the potential for PET MPI to yield fewer false positive study results that lead to further testing.

Imaging equipment was addressed in "Equipment choices." The price of PET and PET/CT cameras varies considerably based largely on features, and so the system's capabilities should be aligned carefully with the goals of the practice so that the investment made is appropriate. In addition to the cost to acquire the camera, the cost to operate and maintain the instrument must be considered. Electricity and cooling requirements may be significant. Both dedicated line-source and PET/CT hybrid cameras can be bought new or refurbished. Refurbished cameras may represent considerable savings and may work well, but would be expected to have a shorter life span and to require more frequent service.

In addition to the capital expenses associated with the cameras and with possible renovations to imaging rooms and patient rooms, the PET radiopharmaceuticals represent significant costs that must be managed diligently for cost-efficiency. Currently, ^{82}Rb is the radiopharmaceutical of choice for PET MPI studies in most centers. The combined storage cart/delivery system (Figure 2) represents a one-time fixed cost. But due to radiological decay of the parent isotope, the ^{82}Rb

generator must be replaced every 28 days at a fixed price, regardless of how many doses were eluted. Patient volume must therefore offset the cost of the generator. Once this threshold is reached, the fixed cost becomes an advantage in the current reimbursement structure that pays for doses or procedures. The paradigm is obviously different for ^{18}F agents, which are usually distributed as unit doses in the United States.

In summary, cardiac PET MPI offers substantial potential benefit to a cardiology practice and its patients as compared with SPECT imaging. This article discussed the many factors to be considered when contemplating such an enhancement in service, including perceived use of the camera system, whether it is an addition or replacement of existing equipment, space considerations, and financial considerations. Those practices that have already made this move have been extremely satisfied with the results.

Disclosure

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