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Valuation of Diagnostic Imaging: Technological Environment

Although medical imaging equipment is used to diagnose many conditions, a large capital investment may be required to obtain it. For example, a magnetic resonance imaging (MRI) machine can cost over $1 million for a refurbished model, and as high as $3 million for a new machine.[1] But beyond the considerable cost of the imaging equipment itself, some machines that employ radiation or powerful magnetic fields to generate diagnostic images have certain architectural requirements in order to be utilized safely. The rooms that house such equipment (referred to as "suites") are built to certain specifications so as to protect those outside the suite, i.e., in the scan room, control room, and/or computer equipment room.[2] Between the machine itself, installation costs, and the suite, a single MRI can ultimately cost between $3 million and $5 million.[3] This final installment of a five-part series on the valuation of diagnostic imaging centers will discuss the technological advancements impacting these enterprises.

Because of the significant level of capital investment, large, integrated healthcare organizations may have an advantage in the provision of diagnostic imaging services, because the initial fixed capital investment is spread over a greater number of patients. In response, smaller healthcare organizations, which may not be able to supply the necessary initial capital investment, often turn to leasing medical equipment in order to provide imaging services.[4]

MRI

MRIs are classified based on the strength of the magnetic field that they generate, which is measured in "*Teslas*" (abbreviated to "*T*").[5] Newer models of MRI machines, i.e., 3T MRIs, can provide efficiency and generate magnetic fields twice as strong as the fields generated by regular MRIs.[6] One of the benefits associated with this advancement is that 3T MRIs may be capable of generating higher quality images in a shorter amount of time, thus improving the ability to diagnose a patient's condition.[7] For example, 3T MRIs may be able to produce images faster than 1.5T MRIs, ultimately improving a provider's efficiency.[8] However, 3T MRIs are significantly more expensive than 1.5T MRIs.[9] In 2017, the Food and Drug Administration (FDA) cleared the first 7T MRI system for clinical use in the U.S., providing more than twice the magnetic field strength of a 3T scanner, resulting in ultrafine image resolution.[10] The continued advancements of MRI machines may indicate that the standard for MRI imaging will change; however, such changes will almost certainly increase the price. Consequently, the pros and cons of each technology must be weighed in order to determine which model is more suited for the organization, as the 3T and 7T MRIs may not be better than 1.5T or 3T MRIs for all purposes.

Other recent advances in MRI technology include: (1) updated software that shortens patient exam times; (2) scanners that allow patients to be positioned at a 90-degree angle, allowing clinicians to pinpoint areas of trouble for those injured in accidents or those with musculoskeletal disorders; (3) scanners that eliminate the narrow tunnels seen in traditional MRI machines, allowing patients with claustrophobia to still have images taken; and (4) scanners that include noise-reduction technology, which may reduce patient stress triggered by the loud sounds that emanate from typical MRIs.[11]

CT

Technological advancements in computed tomography (CT) scanners reflect the need for higher quality images with fewer "*artifacts*" (i.e., discrepancy between the reconstructed image and what is expected)[12] and dosages of radiation. CT scanner "*slices*," or the number of sections in which the CT machine divides the body to image,[13] have been increased in order to improve the quality of CT images.[14] Currently, the standard machinery for a CT is a 4-, 8-, 16-, 32-, 64-, or 128-slice CT; however, other, more advanced CT scanners have incorporated higher slices, including 256, 320, and even 640 slices.[15] The higher-slice systems are thought to lead to better diagnoses, as they have higher quality images, partly due to the decrease in artifacts, in which those using a standard 64-slice scanner may have to discount when assessing CT images.[16] Some of the artifacts seen may be due to breathing and patient movement, affecting image quality.[17] Higher-slice systems are often faster and have a larger imaging area, which may be more realistic for patients that squirm or have faster heart rates, as they reduce the number of artifacts seen on the image due to movement.[18]

It is important to note that there are other components to high-end CT imaging than simply slice numbers that determine the quality of an image that should be taken into account. Previously, CT systems reconstructed images on filtered back projection, due to the short length of time required.[19] Now, all major vendors offer software

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for iterative image reconstruction, which revises the image to clean up artifacts and clarify pixels, allowing the image to run on significantly lower radiation dose scans.[20] Additionally, some CT scanners may incorporate detector technology that utilizes microelectronic circuits or dual-energy spectral imaging to reduce electronic noise and produce sharper images.[21] Wider detector systems have higher sensitivity, allowing iterative construction software to improve contrast and spatial resolutions.[22] The combination of the latest iterative construction and detector technology can reduce the effective radiation dose 20- to 30-fold, reducing exposure to radiation and increasing patient safety.[23]

As the number of slices increases, the cost of the system also typically increases. Although CT scanners have experienced significant advancements, many clinicians still conclude that the 64-slice scanning standard is adequate, as more clinical evidence for the diagnostic difference between the two would be needed to justify the tremendous cost difference for higher-slice systems.[24] When justifying the cost difference, technological advancements improving quality (decreasing artifacts) will need to be addressed in addition to patient volume. High-patient volume could influence the justification for a higher-slice system due to a higher-slice system's ability to scan patients more quickly.[25]

Mammography

Conventional 2D mammography has long been the standard for breast imaging, advancing from originally utilizing x-ray film to the introduction of digital mammography (which most organizations use today) that can be read on computers.[26] A digital mammography utilizes the same technology as film mammography, but incorporates solid-state detectors to convert the x-rays passing through the breast into electronic signals to a computer in order to translate the signals into images.[27] These digital mammography scans improve the ability to manipulate contrast in the image, use computer-aided detection for abnormalities, and often decreases the likelihood of re-takes as compared to 2D film mammography scans.[28]

As high density breasts can often mask cancer and put patients at an increased risk for non-detection, newer advancements are becoming more heavily utilized, overcoming the limitations of 2D mammography.[29] The FDA approved DBT/3D mammography technology in 2011,[30] which allows detection past the dense tissue to view the cancer underneath, because the images are taken at different angles to generate cross sections.[31] DBT uses a low-dose x-ray system to take these cross-sectional images to recreate 3D images of the breast, aiding in early detection and diagnosis of breast cancer.[32] Additionally, a 3D mammogram is relatively fast, producing up to 15 images in four seconds, and allows the breast to be viewed in one-millimeter slices, rather than at full thickness, from the top and side of the breast.[33] 3D mammography is often used in combination with digital 2D mammography, only adding a few additional minutes to the screening.[34] With the advancement of 3D mammography technology, more cancers have been detected and the number of false positives has been reduced. A JAMA Oncology study found that 3D mammography is more effective for breast cancer screening than conventional mammography.[35] In addition, the combination of 3D and 2D mammography has spotted more cancers and reduced the number of false positives than 2D alone.[36]

Mammography is also benefiting from the use of artificial intelligence (AI) technology, which can help clinicians detect issues or diagnose cancer, with AI storing, and learning from, vast amounts of data to catch abnormalities that a radiologist may miss.[37] Studies show that the better rates of cancer detection with AI are promising, but radiologists warn that further evaluation of AI usage in diagnosis may be necessary before drawing conclusions.[38]

Ultrasound

Similar to other diagnostic imaging modalities, ultrasound imaging quality has dramatically improved over the last fifteen years, creating pictures that are more defined and clear.[39] Real-time computer imaging has been able to increase the speed of processing, which also allows for better imaging.[40] This improved imaging quality has resulted in increased diagnosis accuracy.[41]

3D/4D volume transducers create 3D images in real time, allowing sonographers to examine patient anatomy.[42] As techniques for 3D/4D image acquisition start to become more common, sonographers may find themselves re-evaluating workflows in order to increase efficiency while providing accurate and diagnostically relevant results.[43] Additionally, newer ultrasound technology, such as liver imaging, has reduced the need for invasive tests.[44] With the utilization of contrast during an ultrasound, liver lesion diagnostic imaging has allowed for sonographers to diagnose the type of lesion without the need of a biopsy.[45]

Nuclear Medicine

Molecular imaging techniques such as SPECT and PET have been rapidly advancing, with these techniques allowing for the quantification and visualization of molecular processes within the human body.[46] As new imaging agents and radiotracers develop, imaging at the molecular level has become more sensitive and specific, allowing for accurate and earlier detection of diseases.[47] Hybrid imaging, which combines two or more modalities of imaging, has merged anatomical and functional information, which provides a comprehensive view of the processes of disease.[48]

Developments in alpha-emitting radionuclides have shown promising outcomes in the delivery of localized radiation to cancer cells, which in turn reduces the damage to healthy tissue that surrounds cancer cells.[49] Additionally, targeted radionuclide therapy utilizes radioactive substances to bind to specific receptors or cells within the body.[50] This allows radiation to be delivered directly to cells that are diseased, also minimizing the damage to healthy tissues.[51]

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Both AI and radiomics have the potential to positively impact nuclear medicine utilization.[52] Radiomics – when a large amount of quantitative data from medical imagery is extracted and analyzed – can be paired with AI algorithms to process the data to extract information that can predict patient outcomes.[53] AI and radiomics have the potential to assist clinicians in interpreting images, planning treatment, and overall providing more individualized patient care.[54]

Conclusion

Going forward, diagnostic imaging centers will have to overcome a number of challenges in order to remain viable in the U.S. healthcare delivery system. Although diagnostic imaging centers operate in highly competitive environments, patients and payors find those services provided in freestanding centers to be more convenient and less expensive.[55] Notably, Medicare reimbursement for diagnostic imaging procedures has generally decreased over the years, due in part to a complex regulatory environment.[56] Diagnostic imaging centers are some of the most regulated entities in healthcare, with federal, state, and local regulators overseeing providers.[57] Nevertheless, diagnostic imaging technology may allow providers to streamline care and reduce costs through identifying clinical issues early on. Ultimately, this could promote some of the central goals of healthcare reform, i.e., high quality care and increased efficiency.

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