A New Vision for Image Quality in Radiology

Introduction

In the last decade, radiology has seen a focus on reducing radiation doses, resulting in less radiation exposure for patients even with increased number of exams. However, this progress raises a critical question: might an obsessive reduction of dose compromise the quality and diagnostic utility of the images?

What is Image Quality?

Image quality in radiology is primarily reflective of four main image attributes: image contrast, spatial resolution, image noise, and the presence of artifacts[1]. The relevance of each attribute varies significantly depending on the specific diagnostic task at hand. A clear example of this is seen in mammography, where radiologists approach three distinct tasks: detecting calcifications, detecting masses, and identifying soft tissue irregularities. For calcification detection, a high spatial resolution is crucial, but a higher level of noise may be tolerated. In contrast, discerning soft tissue anomalies and masses are more notably affected by contrast and noise. It's only through a comprehensive evaluation of all these image quality attributes, in the context of the clinical requirements, that the true diagnostic efficacy of an image can be fully realized.

Could Radiation Dose Reduction do More Harm than Good?

The relationship between radiation dose and image quality in medical imaging is inherently intertwined. As the medical community diligently and rightfully works towards reducing radiation doses, this inevitably alters the quality of the images produced. Importantly, compromised image quality can present risks that can surpass the potential harm associated with radiation exposure. It is therefore imperative to find a harmonious balance between minimizing radiation dose and preserving the diagnostic integrity of the images. This balance is essential for providing optimal patient care and ensuring accurate diagnoses. Caution is necessary, as even the most well-intentioned efforts can lead to unintended and potentially adverse outcomes.

A Cautionary Tale

An illustrative example of well-intended performance objectives leading to unintended consequences is evident in the National Health Service (NHS) of Great Britain's efforts to reduce patient wait times in Accident and Emergency (A&E) departments. In 2004, the NHS set a target for 98% of A&E patients to be seen within a four-hour window. Health trusts failing to meet this benchmark faced financial penalties, a measure aimed at enhancing care for

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critically ill patients. Initially, this strategy seemed successful, with significant improvements in meeting the four-hour wait time goal. However, soon, unintended effects emerged.

The principal unintended consequence was the skewed prioritization of patients nearing the four-hour mark. Once this threshold was passed, the urgency diminished, leading to those who breached the limit experiencing drastically longer wait times, averaging around eight hours. An alarming investigation at one hospital revealed that approximately 1,200 patients died over three years due to these unintended outcomes[2]. In efforts to meet the four-hour targets, medical staff often redirected their attention from severely ill patients to those with minor ailments. Consequently, patients who exceeded the four-hour target frequently endured prolonged periods awaiting care, some recalling hours-long waits covered in blood, devoid of food, water, or pain relief. The target has since undergone several revisions to lower its threshold and refocus on urgent health issues, acknowledging that the original goal was not clinically justifiable. This incident stands as a stark warning.

A similar situation is observed in the context of efforts to reduce radiation doses, notably exemplified by the Leapfrog pediatric radiation dose reporting[3]. The Leapfrog annual survey includes a section evaluating hospitals on their pediatric radiation doses, incentivizing lower doses. However, as the benchmark for radiation doses continues to drop, hospitals remain pressured to reduce doses further, potentially at the expense of image quality. This raises critical questions: How can we determine when radiation doses are optimally lowered without impairing diagnostic quality? Will this intense focus on reducing radiation doses inadvertently lead to compromised patient care? Can we have measures that ascertain the appropriateness of image quality akin those we use for dose?

How Can Image Quality Be Measured?

Traditionally, assessing the diagnostic quality of clinical images has been subjective, reflecting the complex and multifaceted nature of image quality. The challenge with the subjective approach is that expert opinions significantly vary across and within experts, making its systematic application impossible, let alone the limited availability of expert radiologists. As an alternative, objective measures of image quality have been developed, primarily through phantom studies. However, these objective methods face a significant limitation: they cannot replicate the patient-specific factors encountered in real-world clinical settings. Consequently, there exists a noticeable disconnect between the image quality metrics derived from phantom studies and the actual images used in clinical practice. This highlights a critical area in need of improvement for better patient care.

A novel approach to address this challenge is the direct measurement of image quality within patient images themselves. The pioneering effort in this field involved the assessment of 10 distinct image attributes from clinical chest images[9]. This approach of so-called *in vivo* image quality assessment has been extended to the overall noise level, noise texture, and spatial resolution in clinical CT images[10,11,12]. Collectively, these automated *in vivo* image quality measurement techniques represent the most scalable and effective strategy for assessing image quality to date. They not only provide a

practical solution but also pave the way for future advancements in ensuring optimal image quality across various imaging modalities.

What Is Happening Around Image Quality Today?

The current landscape in radiology is at a crucial juncture, especially with the introduction of a new quality measure by the Centers for Medicare and Medicaid Services (CMS). This measure is unique in that it evaluates both radiation dose and image quality, with a specific focus on radiation dose and a measure of global noise level associated with CT images, potentially impacting hospital finances.

While this initiative marks a step towards harmonizing radiation dose and image quality, it's not without its limitations. Relying solely on the global noise level measured in air as a measure of image quality significantly oversimplifies image quality. For instance, it is well established that image processing methods, including the use of varied reconstruction kernels and iterative reconstruction techniques in CT can notably alter noise and image quality in different ways. Adjusting radiation dose or targeting an image noise level does not ensure the same visibility of lesions as in standard dose images[13,14]. In fact, considering the most important attributes of image quality, radiologists prioritize over noise many other image quality factors, such as motion, contrast, and resolution[15].

The CMS quality measure, though a pivotal acknowledgment of the importance of image quality, highlights the need for a comprehensive framework to evaluate image quality and put it in balance with dose. Hospitals now find themselves at a crucial decision point, figuring out optimal strategies to adhere to and report on this new standard. The absence of a clear and well-defined approach risks a misplaced focus on quality of radiological practice, potentially leading to unintended negative effects. This situation emphasizes the urgent necessity for a unified and effective strategy to address the complexities and evolving demands of image quality in radiology.

Is More Data Always Better?

In the era of dose reduction, radiation dose monitoring programs have become a staple in radiology departments. However, most of these programs primarily function as repositories for vast amounts of dose data, leaving the intricate task of data management and analysis to the end-users. The process of protocol mapping within these systems is not only time-consuming but also prone to errors. Moreover, many dose alerts generated turn out to be false positives, complicating the process of identifying genuine areas for improvement. In our eagerness to implement new tools for reducing patient dose, we may inadvertently increase the workload of hospital staff, diverting their focus from their primary duty of patient care.

As we turn our attention to image quality in addition to dose, it is crucial to learn from these experiences. Although monitoring image quality shares some characteristics with monitoring radiation dose, it is significantly more complex. The risk of overwhelming clinical staff with difficult-to-interpret data is even greater in this context. Therefore, it's essential that we ensure image quality data is not only accurately collected but also presented in a way that is clinically relevant and easily understandable. This vigilance is key to

integrating image quality monitoring effectively into clinical practice without adding undue strain on healthcare professionals.

What is Imalogix's Vision?

Our mission is crystal clear: to uncover how and where healthcare delivery can be improved.

Our approach is grounded in several key principles:

- Empowering Hospital Staff: By liberating staff from the complexities of data management, they can focus more on their primary tasks and associated quality improvement.
- Advancing Evidence-Based Practice: Our strategies are rooted in robust scientific research, ensuring that our approaches are evidence-based, effective, and reliable.
- Ensuring Clinical Relevance: We understand that quality is deeply intertwined with the intricate realities of clinical tasks. Recognizing and embracing these nuances is vital for our mission.
- Streamlinng Information Delivery: We commit to presenting complex information in a simplified, clear, and user-friendly manner. This ensures that all healthcare professionals, regardless of their expertise level, can easily comprehend and utilize the data effectively in their practice.
- Embracing Collaborative Progress: We believe in the power of collaborative learning and cross-hospital comparisons as key drivers of healthcare advancement.

We recognize the multifaceted nature of image quality and dose, and their critical role in ensuring quality healthcare. By adopting a comprehensive and realistic view of image quality, we aim to contribute significantly to the field of radiology.

What is Next?

We call upon healthcare institutions, radiologists, technologists, and policymakers to join us in this pursuit of safeguarding quality imaging in the broad sense of that word beyond dose alone. To take the next step towards this vision, we invite strong collaboration and cooperation across all stakeholders and in the discourse about the future of diagnostic imaging and its continued effectual contribution to human wellness. Together, we can transform the landscape of diagnostic radiology, improve patient care, and ensure that image quality remains at the forefront of our healthcare priorities.

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