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Tumor Sizing Technology: Investigating Current Methods and Possible Technological Improvements

Abstract:

The precise measurement of tumors is critical for cancer diagnosis, staging, and treatment. With rapidly advancing imaging technology, the manual techniques of measuring and estimating tumors have evolved to digitally allow doctors to perform accurate measurements of the size of a tumor efficiently and reliably. Nevertheless, imaging technology has yet to keep pace with advances in tumor visualization tools that could improve the precision of clinical measurements. Such developments in tumor sizing technology will be addressed in this review, taking in current imaging modalities such as CT, MRI, PET, and emerging computational technologies, including those based on 3D modeling, virtual reality, and artificial intelligence. By evaluating them in conjunction, this review hopes to illustrate the pathway to improved staging, enhanced treatment planning, and ultimately more effective outcomes through technological advancements.

Introduction:

In oncology, the precise measurement and characterization of tumors are critical for diagnosing and staging the disease as well as monitoring its progression. Dependable imaging

modalities continue to define the primary extent of the disease, treatment plans, and follow-up evaluations. However, determining the best imaging modality can be complex, as factors such as tumor location, tumor size, tumor accessibility, and patient demographics like age and general health condition can differ between patients. Conventional techniques like computerized tomography, magnetic resonance imaging, and positron emission tomography have their advantages and disadvantages. Traditional methods have clear limitations due to their inaccuracy in dimensions, especially with irregularly shaped tumors.

In 2000, the Response Evaluation Criteria in Solid Tumors (RECIST) criteria were developed to standardize and improve the evaluation of solid tumors by providing a framework to systematically evaluate changes in the size of tumors and their response to therapy. While RECIST has been of great value for clinical trials and practice, it has limitations, particularly for tumors that do not shrink uniformly or are located in complex anatomic areas. New computational technologies can also address these shortcomings: virtual reality (VR), for instance, can enhance the precision and reproducibility of tumor measurements thanks to 3D imaging. Using VR and 3D, healthcare providers can view tumors from multiple angles, potentially altering the current application of RECIST and transforming cancer care by providing more elaborate and reliable assessments. Here, we will discuss traditional tumor measurement methods, the RECIST criteria, and how VR and 3D advancements will change the landscape of cancer diagnostics and evaluation of treatment response.

Traditional Tumor Sizing Methods and Their Limitations:

Accurate tumor sizing can help diagnose cancer, stage it, and assess how well a treatment works. However, there are many types of cancer with varying locations and patient needs, making it challenging to determine the best way to assess the disease. Each imaging technology

has its specific advantages and disadvantages. This makes it important for clinicians to consider the trade-offs of each method before settling on a diagnostic and monitoring regimen. Ideally, an imaging method should yield similar results between scans, allowing for appropriate surveillance of lesions over time and minimizing variation in outcomes between imaging sessions. Such precision is crucial in areas such as cancer staging and treatment planning, where information such as tumor size, location, and response to therapy are critical in guiding medical decisions.

Computerized Tomography (CT) scan is one of the most widely used tools for cancer diagnostic and follow-up purposes. CT scans use a series of beams of X-rays rotating around the body to create detailed cross-sectional images as if slicing through internal structures. CT scans are favored by physicians for their accessibility, speed, and standardized imaging quality, which helps monitor tumor size changes over time. These scans often utilize a contrast dye injected intravenously to improve the visibility of certain regions (such as blood vessels surrounding a tumor), which is vital when determining a tumor's blood supply. However, because of the ionizing radiation in CT scans, patients are exposed to a small incremental risk of developing cancer, meaning CT scans should not be conducted unnecessarily. This radiation exposure is a significant consideration for patients who require multiple scans over time, such as patients undergoing long-term treatment. Additionally, patients allergic to the contrast dye can experience adverse reactions and may require non-contrast scans that do not provide the same level of detail.

Radiation exposure from CT scans poses a particularly high risk of radiation exposure for vulnerable populations, including pregnant women and young children. Magnetic Resonance Imaging (MRI) tests can be a safer option for these instances. MRI does not involve ionizing radiation but uses large magnetic fields to produce high-contrast images of soft tissues. This is especially helpful for imaging tumors in places like the brain, spinal cord, and soft tissue, where

CT is less effective. Like CT, MRI sometimes requires contrast agents to enhance clarity, though the powerful magnetic field makes MRI unfit for patients with metallic implants, including pacemakers. MRI scans, on the other hand, are often more time-consuming and expensive than CT scans, which may limit their use in more routine settings.

Another alternative is Positron Emission Tomography (PET) scans, which can measure cellular metabolism and help look at cancers that do not have significant structural changes but are metabolically active. PET scans use a radioactive glucose tracer that cancer cells take up in greater volume than normal cells. The PET scanner picks up gamma rays emitted from the tracer, producing a 3D image that shows areas of increased metabolic activity, which is particularly useful for monitoring the spread of cancer and responses from treatment. However, PET scans are also associated with risks from radiation exposure, and patients with diabetes may have to withhold from PET imaging because altered glucose levels can interfere with the results.

Sometimes, more limited imaging options may be used for specific cases. Chest X-rays, for example, may help detect lung cancer in specific instances, but are typically followed up by CT scans, which have better resolution. Clinicians might also perform clinical lesion assessments for superficial tumors. These superficial assessments for non-nodular lesions more significant than 10 mm are conducted using calipers, and photographic evidence of changes (color) may or may not be used in identification. While these methods can be helpful, they lack the depth and precision necessary for most internal tumors, further emphasizing the importance of tailored imaging techniques for different cancer types.

Tumor Sizing Criteria: RECIST Criteria Overview, Revisions, and Challenges:

Accurate tumor measurement is important in oncology as a significant aspect of treating, monitoring, and assessing response to therapy. Over the years, tumor sizing criteria have

changed significantly, and the Response Evaluation Criteria in Solid Tumors (RECIST) criteria have become an essential standard used in clinical trials and everyday practice. The Response Evaluation Criteria in Solid Tumors were developed to provide an objective, consistent method to evaluate changes in tumor size and response to therapy that would be comparable across studies and therapies. As cancer treatments have advanced, RECIST has been refined to ensure it remains applicable. This review provides a brief history of RECIST, its evolution, its shortcomings in the context of real-world environments, and other criteria developed to overcome these limitations.

Developed in 2000 by an international committee including members from the European Organization for Research and Treatment of Cancer (EORTC), the U.S. National Cancer Institute (NCI), and the National Cancer Institute of Canada (NCIC), the RECIST criteria sought to provide a standard method for assessing tumor response in clinical trials. Prior to RECIST, guidelines from the World Health Organization (WHO) in the 1980s used bidimensional assessments, where the product of the two largest perpendicular diameters of a tumor were used. However, these approaches tend to be hard to implement consistently, resulting in differential treatment of how responses are judged. RECIST addressed these problems by measuring the longest diameter of a tumor lesion, simplifying it for consistency. According to RECIST 1.0, tumors were assessed as a complete response (CR), partial response (PR), progressive disease (PD), or stable disease (SD) based on changes in their longest dimensions. This system soon became popular in oncology clinical trials, offering a more standardized method to compare treatment outcomes between different studies and institutions. The RECIST criteria were subsequently reviewed in 2009, and new criteria were established called RECIST 1.1 to reflect advances in imaging technology and address some of the challenges seen in practice. One of the main changes in this update was reducing the number of lesions measured from ten to five total

target lesions (a maximum of two per organ), making the process less cumbersome. They also established that lymph nodes could only be deemed measurable if larger than 15 mm in the short axis to minimize potential inaccuracies related to smaller lymph nodes. In addition, the revision clarified that a minimum increase of 5 mm is required for a lesion to be considered a progressive disease. Once again, in 2016, RECIST published a new set of criteria, iRECIST, that was explicitly aimed at addressing some of the issues with standard RECIST 1.1 in the setting of immunotherapy. Immunotherapies may result in a transient increase in tumor size due to immune cell infiltration (negative non-representative tumor response). This phenomenon, known as pseudoprogression, could be misinterpreted as real tumor growth. The iRECIST criteria also introduced the concept of "unconfirmed progression," or iUPD, meaning that physicians can hold off on determining the actual progression until the imaging is done again. This adjustment allows physicians to assess how effectively patients are responding to immunotherapy in trials more consistently.

Unfortunately, there are challenges to using RECIST, especially in real-world clinical environments with added tumor complexity. One problem is that it measures tumors in a single dimension and may not capture how tumors with irregular shapes can change or grow in unusual ways. For instance, if a tumor grows width-wise instead of length-wise, it may not be deemed progressive under RECIST even though it has grown. Likewise, treatment-related cystic or necrotic changes can make tumors appear smaller on imaging without a corresponding decrease in functional tumor tissue. Alternative response criteria have been proposed for various cancers to overcome these issues.

Considering the limitations of RECIST, alternative response criteria have been developed for specific cancer types or treatment contexts. One example was the modified RECIST (mRECIST) used for Hepatocellular Carcinoma. This version focuses on only the "viable" portion of a tumor

(i.e., the part that's not necrotic or dead and does not signify active disease), making this a more accurate method of measuring response to treatment in liver cancer trials. Another key advancement is the Lugano Classification for lymphomas. This classification supersedes RECIST to accommodate the unique biology of hematologic malignancies. This system incorporates PET imaging to evaluate metabolic activity. Measuring metabolic activity provides greater insight into treatment response for these types of cancers, especially in circumstances where a purely size-based response might be deceiving. These alternative standards are meant to augment RECIST's usefulness in some specialized situations, providing a more sophisticated interpretation of therapeutic responses. These different criteria allow healthcare professionals to have a better overview of tumors, thus individualizing treatments and enhancing patient outcomes.

In summary, RECIST has changed the game in oncology, providing a consistent, standardized method to gauge response to treatment, allowing similar comparisons across studies. However, it is important to mention that RECIST also has limitations, especially in the context of assessing irregularly shaped tumors, response to immunotherapy, and dynamic changes in tumors, which has led to modifications of RECIST over the years to address the changes in response to treatment. mRECIST and the Lugano classification provide ways to fill in these voids, marking the transition toward a more tailored approach for measuring tumors. Together, RECIST and these specialized criteria are evolving in the pursuit of precision oncology, where accurate measurements are crucial to enhancing the quality of patient care.

Computational Innovations in Tumor Measurement:

Advancements in computational technology are profoundly impacting the oncology field by enhancing how tumors are visualized, measured, and monitored. Tumor measurement has

traditionally been based on 2D imaging. However, exciting new developments, including 3D modeling, virtual reality (VR), artificial intelligence (AI), and machine learning (ML) technologies are now coming into play. These tools allow oncologists to access more in-depth, accurate information about tumor behavior, which enables personalized, targeted, and more effective treatment choices. By enhancing the RECIST framework, these innovations have the potential to reshape clinical practices to ensure better patient outcomes.

3D modeling and virtual reality can revolutionize how we approach cancer treatment. This technology can provide oncologists with immersive, interactive, and precise visualizations of tumors that no traditional imaging method can match. These technologies provide greater spatial information about a tumor's size, shape, and position, which is applicable mainly in complex cases. An example of such use is VR for oncologists, who can now view tumor structures in a completely immersive 3D environment. This results in significant insight into surgical planning and treatment approaches. Perhaps one of the most potent applications of VR is its use in planning surgery on complex tumors. One great example is from the Cleveland Clinic, where surgeons use VR to map out surgery on liver cancer patients. In one case, the technology helped a surgeon visualize the precise location of a tumor relative to important blood vessels and other neighboring organs. This knowledge was key to shaping a less invasive surgical strategy that would be challenging to reach without standard 2D imaging. Another similar example was outlined by The Journal of Thoracic and Cardiovascular Surgery, which outlined VR use in examination of small intrapulmonary metastases. This article describes the surgical benefits of virtual reality and artificial intelligence in augmenting scans and allowing for surgical teams to visualize and customize their surgical planning before performing surgery on a patient. These examples illustrate a prime setting where VR is critical: addressing tumors near sensitive structures, such as the brain, spine, and liver, where even minor measurement errors can have

enormous implications. However, VR is helpful not only in planning surgeries but also in simulating potential outcomes of treatments. Oncologists can work with virtual reality (VR) technology developers to build simulated tumor models using a single patient's imaging data. Such simulations track how a tumor would respond to different treatment regimens, allowing doctors to tweak or change their strategies as needed. By offering a dynamic and holistic view of a tumor's structure, VR provides a promising new layer of understanding, helping clinicians make informed decisions and leading to more precise and effective cancer care.

In addition to virtual reality, artificial intelligence and machine learning are changing the nature of cancer imaging by enabling processes that used to take a lot of time and expertise to happen automatically. The place where AI is revolutionizing the industry the most is in segmentation, a process where radiologists draw the contours of a tumor on an imaging scan. This is often a challenging task, particularly in the case of tumors with shapes that are irregular or fuzzy around the edges. Nevertheless, AI has been surprisingly accurate here. Algorithms trained on massive datasets of labeled images routinely perform these segmentation tasks accurately and quickly, sometimes equal to or better than a human expert. This ability is crucial in complicated cases, where even minor errors in outlining a tumor can result in inaccurate assessments of how much it has grown or how effective a treatment is. AI is also becoming very powerful in predicting how tumors develop and how they respond to therapies. These models are trained on several imaging data modalities, including previous information about the patient and tumor features, to predict the behavior of a tumor in certain situations. For instance, scientists have created algorithms that analyze serial CT or MRI scans to predict not just tumor growth but also the risk of metastasis. By tracking changes in imaging features over time, these models can help oncologists anticipate how a tumor may evolve, enabling more proactive treatment decisions.

Moreover, AI-powered applications are being developed to analyze therapies' real-time efficacy. These tools can sift through imaging data obtained during treatment, giving insights into how well a tumor responds to treatment and whether adjustments are needed. The application of AI and ML significantly minimizes discrepancies in diagnoses made by different radiologists and decreases human error. In clinical trials, AI standardizes measurements and consistency, which is critical for accurately comparing the effectiveness of different treatments. Tumor measurement can be complicated in extensive, multi-center studies, so this standardization is essential. The introduction of AI and ML provides unprecedented accuracy and effectiveness in cancer imaging, ultimately leading to enhanced diagnostic accuracy, improved therapy planning, and better patient monitoring. In the future, integrating 3D modeling and VR with the RECIST framework to incorporate AI into oncology may be significant. RECIST currently tracks changes using one-dimensional measurements, using the longest diameter of a tumor. However, complex or irregularly shaped tumors are often not accurately measured by a single measurement, as they can grow or shrink in different directions, and different tumor regions may have different responses to treatment. With the use of 3D/VR technologies, a more holistic analysis of tumor responses to therapy may emerge through future iterations of RECIST.

To recap, 3D modeling and VR technologies give a new view that can engage how tumors evolve. Using a volumetric method, the RECIST criteria are not limited to length but may include depth, width, and volume. With VR, doctors could view tumors from all angles, detecting subtle patterns of growth or shrinkage that would go unnoticed in a traditional 2D scan. Incorporating 3D data could make the method more accurate, particularly for tumors that are non-symmetrical or that respond non-uniformly to treatment. Adopting VR-compatible technology could improve real-time tracking of complex tumors, giving clinicians a clearer picture of how well treatments work. Another possible benefit is that machine learning can

automatically demarcate tumor borders, assess measurements, and increase accuracy over multiple imaging sessions. AI can comb through vast amounts of patient data to identify patterns in tumor behavior. In addition, AI may be able to distinguish pseudoprogression, the temporary appearance of a tumor within the body that is larger as a result of immunotherapy, from actual tumor growth when inflammation related to an immune response is detected. Such an approach would enable more consistent iRECIST evaluations and decrease the misinterpretation rate in patient monitoring. On top of these benefits, AI-powered tools could help physicians forecast how and when a tumor may change in response to treatment, helping further customize RECIST to the clinic's needs. Combining 3D, VR, and AI technologies, RECIST criteria has the ability to evolve from a mainly 1-D standard to a more multidimensional approach, reflecting tumor traits more accurately. These advancements would provide oncologists with deeper insights into tumor responses and establish more nuanced criteria for evaluating treatment effectiveness. This new era of reviewed RECIST-compatible standards deployed in 3D with predictive analytics will offer significant advancements in oncology and provide more individualized patient monitoring and treatment options.

Challenges and Future Directions for Technology Adoption:

Integrating advanced technologies like virtual reality, artificial intelligence, and 3D imaging into oncology promises to revolutionize cancer care. These innovations offer unprecedented capabilities for precise tumor measurement, treatment planning, and patient monitoring. However, their adoption in routine clinical practice faces significant challenges. It is necessary to address these obstacles and consider future directions in research and policy to ensure equitable access to these advancements across all patients.

Adopting VR, AI, and 3D imaging in oncology practice faces several practical and systemic hurdles. One major obstacle is the need for specialized training. Oncologists, radiologists, and surgical teams must also adapt to these tools, a process that will take a significant investment of time and resources. Many healthcare professionals will be unfamiliar with VR systems or AI tools, and effective use of these technologies will require both technical expertise and a solid understanding of their clinical applications. This knowledge gap can be addressed by implementing training programs; however, these can be expensive and time-consuming.

Another major challenge is the high cost associated with these technologies. VR systems, advanced AI models, and high-quality 3D imaging require a significant investment in hardware and software, both in terms of upfront purchase and ongoing maintenance costs. These tools may not be financially accessible for the smaller hospitals and clinics often found in underserved areas. Computational imaging with high-performance systems also depends on sophisticated computing infrastructure that is not as ubiquitous at most locations. In many regions, healthcare facilities need help with basic imaging capabilities, let alone being introduced to cutting-edge computational systems. This disparity risks widening the gap in cancer care between well-funded institutions and resource-limited settings.

Access to more advanced computational resources is also a limitation to broader implementation. Effective AI and 3D imaging entry points often require robust data storage and processing capabilities that smaller health networks do not have. Although cloud-based solutions could alleviate some of these problems, they raise their issues of data security and privacy.

Additionally, deploying these technologies within existing workflows could create logistical headaches because many current healthcare systems are not designed to accommodate this level of complexity. Also, imaging components in VR technology will still not be a walk in the park, given that it will require a voxel painter that produces volumetric pixels for 3D imaging. While

there are voxel painters for other applications, there is currently not one specifically for 3D cancer imaging. Keeping these challenges in mind, we must advocate for solutions, ensuring that these cutting-edge technologies can be integrated into cancer care with the same ease, benefiting all patients.

Conclusion:

The examination of tumor sizing technology, its current limitations, and its future possibilities underscores the intricate relationship between currently outdated tumor measurement methods and new potential improvements. By analyzing the role of current imaging techniques, the application of RECIST criteria, and the advancements in computational tumor sizing methods, it becomes evident that significant opportunities exist to enhance the precision and reliability of cancer evaluation. These improvements are essential for optimizing treatment strategies and improving patient outcomes and quality of care. The discussion highlights the importance of recognizing the current limitations of tumor sizing technology, such as the challenges of measuring complex or irregularly shaped tumors and the constraints of existing standards like RECIST. Addressing these issues requires embracing emerging technologies, including artificial intelligence, 3D modeling, and virtual reality, which offer the potential to revolutionize how tumors are assessed and monitored. These tools can provide a more comprehensive and dynamic understanding of tumor behavior, enabling clinicians to make more informed and personalized treatment decisions.

Looking ahead, it is clear that innovation alone is not enough. Success will depend on a collaborative approach that integrates new technologies into clinical workflows while addressing practical barriers such as cost, accessibility, and the need for specialized training. Moreover, careful evaluation of these technologies through rigorous research and clinical validation will be

critical to ensuring their safety, efficacy, and ethical use in oncology. Ultimately, the future of tumor sizing technology lies in the ability to adapt and evolve in response to the ever-changing demands of cancer care. By prioritizing innovation, critical evaluation, and a commitment to equitable implementation, the medical community can pave the way for transformative advancements that bring precision oncology closer to reality.

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