Updates in volumetric-modulated arc therapy for prostate cancer

Mary Beth Massat

Clinical use of volumetric-modulated arc therapy (VMAT) has grown significantly since its debut in 2007. An earlier form of VMAT known as intensity-modulated arc therapy (IMAT) was introduced in 1995 by Cedric X. Yu, DSc, FAAPM, professor of radiation oncology at the University of Maryland School of Medicine, Baltimore. The difference was that IMAT required the use of multiple superimposed arcs for dose distribution, while VMAT allows the entire target volume to be treated using 1 or 2 arcs.[1] Essentially, VMAT is an arc-based approach to intensity-modulated radiation therapy (IMRT).

Since the prostate is one of the most common sites treated with IMRT, it's no surprise that VMAT may soon supplant IMRT as a preferred method for delivering external-beam radiation therapy. A 2011 review of literature and clinical use found that several studies reported significant improvement in OAR (organs at risk) sparing with VMAT. Most studies also determined that the key difference between VMAT and fixed-field IMRT is VMAT's ability to reduce treatment delivery time and monitor units (MU).[1]

"The application of VMAT for prostate cancer has been well-demonstrated for both plan quality and efficiency," says Dr. Yu, who has studied VMAT techniques and published numerous papers and book chapters on the topic.

Mary Beth Massat is a freelance healthcare writer based in Crystal Lake, IL.

At Terk Oncology Center for Prostate Cancer and Breast Conservation, Jacksonville, Florida, radiation oncologists Mitchell D. Terk, MD, and Jamie Cesaretti, MD, have treated more than 8,000 men for prostate cancer, exclusively using VMAT for external radiation therapy of the prostate. "Modulated arc therapy is ideal for small, centrally located cancers, such as prostate," Dr. Terk says. "With a 360-degree modulated arc, we can spread the dose away from critical structures such as the rectum and bladder."

When Drs. Terk and Cesaretti opened a new clinic 2 years ago, they implemented a linac and treatment planning system capable of performing VMAT. Today, their prostate treatment plans with VMAT can routinely deliver over 81 Gy up to 86.4 Gy for patients with bulky tumors, while keeping the bladder and rectum doses at less than half of the tolerance doses recommended by the Radiation Therapy Oncology Group (RTOG) and the Proton Therapy Consortium guidelines, significantly lowering complication rates.

Dr. Terk uses VMAT for treating prostate cancer patients unless patients opt for brachytherapy. His team has performed 5,000 seed implants since 1997. Typically, they offer brachytherapy as an option for monotherapy in men with early stage prostate cancers, or if the patient has recurrent, localized disease after prior external radiation such as proton therapy. For more locally advanced disease, patients may receive combined brachytherapy and a lower dose of VMAT.

VMAT can be delivered as either constant-dose-rate or variable-dose-rate plans. In the literature, VMAT is most often described as a single arc technique that employs dose rate variation.[1]

"In theory, variable dose rate is not absolutely needed to achieve the best plan quality," Dr. Yu explains. "However, most planning system vendors did not restrict the dose rate to be constant, and therefore require the variable dose rate capability." He cautions that not all linacs can be upgraded to support variable dose rate.

Similarly, the use of single arc or dual arc has also been studied. "Generally speaking, when 2 arcs are used, the planning system has an easier task in keeping the lengths of MLC movements within the MLC's abilities, and results in a better plan and smoother delivery," says Dr. Yu. "For the same reason, the plan quality also improves with dual arcs."

James Chow, PhD, FCCPM, assistant professor and medical physicist at Princess Margaret Cancer Centre in Toronto, Ontario, Canada and the University of Toronto, agrees that the more arcs used, the better the plan. However, it is important to minimize the number of arcs to decrease the time the beam is on, he says. "The double-arc technique resulted in a prostate VMAT plan with better prostate coverage and rectal dose-volume criteria compared to the single-arc," with a tumor control probability of 0.16% higher than the single-arc,[2] wrote Dr. Chow and co-author Runqing Jiang, PhD, MCCPM, in a 2013 paper.

Dr. Chow explains that the prostate typically has one target compared to the

At Terk Oncology Center for Prostate Cancer and Breast Conservation, Jacksonville, Florida, prostate treatment plans with VMAT can routinely deliver over 81 Gy up to 86.4 Gy for patients with bulky tumors. Pictured here is the center's linac used in VMAT. Photo courtesy Terk Oncology.

head and neck, which has more critical structures and often multiple targets. Determining the number of arcs when using VMAT depends on the complexity of the target and surrounding anatomy, he says.

While VMAT plans using 2 arcs may surpass one-arc plans, the decision is patient-specific, Dr. Terk says. The important considerations are dose distribution, patient-specific anatomy, and prostate size. A large or unusually shaped prostate, small bladder, or hip replacement are the most common factors increasing treatment plan complexity. "The more complicated the patient, however, the greater the benefit of these advanced technologies," he says.

Gains in Efficiency

A well-known advantage of VMAT is its ability to deliver faster treatments. According to Dr. Chow, one technology that enhances the efficiency of treatment technology is flattening filter-free beams (FFF). FFF beams operate at higher dose rates—over 1,000 MU/min and greater—which also shortens beam-on time and reduces overall treatment time.

A recent study examining the effect of FFF and VMAT delivery found that a 10 MV (maximum dose rate of 2400 MU/min) FFF VMAT plan configuration provided the greatest improvement in treatment efficiency, with high dose per fraction cases (stereotactic radiation therapy and stereotactic body radiation therapy) realizing the highest gain.[3]

"VMAT is beneficial for the hospital and the patient," Dr. Chow explains. "Because treatment is completed quicker, it helps reduce the possibility that intra-fraction motion will occur, which can lead to the beam hitting something that is not targeted. By finishing patient treatments sooner, the hospital can also increase patient throughput."

While patient motion is a concern, respiration typically is not a significant issue when treating the prostate with VMAT, although some sites may use gating. However, whether the bladder and rectum are filled or empty makes a difference, Dr. Chow says. At Princess Margaret Cancer Centre, patients are treated with a full bladder and empty rectum to help ensure the location of the anatomy is consistent for each treatment.

At Terk Oncology, a patient's immobilization device and rectal balloon are routinely used to minimize patient motion, intra-fraction prostate motion, and rectal doses. The balloon helps distend the rectum away from the prostate, further reducing dose to the critical area, Dr. Terk explains. Fiducial markers and daily kilovoltage cone-beam CT (CBCT) imaging is also performed to verify alignment of the prostate and critical structures before each treatment.

Improving Accuracy

In terms of treatment delivery, little more can or should be done to improve the process; however, there is room for improvement in geometric accuracy, Dr. Yu adds. One way to accomplish this is with real-time guidance of the linac based on imaging performed immediately before treatment delivery, such as with CBCT affixed to the linac.[2] Dr. Yu predicts that over the next decade, the industry will see more advanced image-guided radiation therapy (IGRT) systems and wider adoption of the technique.

MRI also can play a role, evidenced by Dr. Terk who has routinely used MRI treatment planning since 2009 to assist with IGRT. "We can far better visualize the prostate and surrounding anatomy with MR compared to CT," Dr. Terk says. "We fuse the MR image with CT in our treatment planning system to outline the anatomy and ensure we don't miss the lesion or hit any critical structures."

In fact, Dr. Terk believes that MR-guided radiation therapy will provide notable incremental improvements in treatment quality. "Image guidance is the big advantage of VMAT over proton therapy," he says. Because of the imaging capability, Dr. Terk believes VMAT is superior to proton therapy for treating prostate cancer.

While advances in treatment delivery technology have been limited since the inception of IMRT nearly 20 years ago—and by extension VMAT— the future holds promise. "A method that can deliver proton-like dose distribution with photons," would be ideal, says Dr. Yu.

References

1. Teoh M, Clark CH, Wood K, et al. Volumetric modulated arc therapy: a review of current literature and clinical use in practice. *Br J Radiol.* 2011;84(1007):967-996.
2. Chow JCL, Jiang R. Prostate volumetric-modulated arc therapy: dosimetry and radiobiological model variation between the single-arc and double-arc technique. *J Appl Clin Med Phys.* 2013;14(3):4053.
3. Thomas EM, Popple RA, Prendergast BM, et al. Effects of flattening filterfreeand volumetric modulated arc therapy delivery on treatment efficiency. *J Appl Clin Med Phys.* 2013;14(6):4328.