Several developments are combining to move radiation oncology into a new era—the 3-dimensional conformal radiation therapy (3-D CRT) era. Modern imaging technologies provide a 3-D view of the cancer patient's anatomy that allows the radiation oncologist to more accurately identify tumor volumes and their relationship with other tissues. The power and reliability of computers continues to increase rapidly while the costs continue to decrease. These advances have spurred the development of CT-simulation/3-D radiation treatment planning systems that are the cornerstones of the 3-D CRT era [1-3].

In the 1960s and 1970s, the dedicated x-ray simulator revolutionized the planning of radiotherapy and is now recognized as an essential piece of equipment for the practice of radiation oncology. The new dedicated CT-simulation/3-D planning systems, which provide efficient integration of CT-based target volume and normal tissue definition with the process of radiation therapy treatment planning, are likely to again revolutionize the planning process and replace the conventional simulator and the 2-D dose planning systems by the end of this decade [4].

Stephenson and Wiley present an enthusiastic report on their early clinical experience with one of the first commercial CT-simulator systems (Picker ACQSIM). The article is a welcome addition to the literature, as it may help some radiation oncologists and physicists who are resisting the change in technology to see more clearly the added value of CT-simulation/3-D planning.

**The CT-Simulation/3-D Treatment Planning Process**

As the authors point out, CT-simulation/3-D planning requires a different perspective and expectation of simulation. Specifying target volumes and organs at risk by drawing contours on CT images on a slice-by-slice basis, as opposed to drawing a portal on a simulator radiograph, is a major paradigm shift for the radiation oncologist.

First, it must be understood that the CT scanner is simply the data gathering tool used in the CT-simulation/3-D planning process. Once a patient's digital anatomic information has been obtained by a volumetric CT scan, the simulation/planning task becomes a virtual process and is performed with a computer workstation using software tools developed specifically for simulation and planning the cancer patient's treatment [5-7].

The CT-simulation system described by Stephenson and Wiley allows for rapid data acquisition, efficient contouring of key structures, the selection of an isocenter either manually or computer calculated, and 3-D reconstruction with the generation of a digitally reconstructed radiograph (DRR) with the target volume and/or critical structures superimposed upon the film. The CT-simulation software used for contouring normal structures and target volumes and virtual simulation has been advanced significantly as robust commercial systems are rapidly replacing homemade software. The treatment planner/radiation oncologist can now draw contours around the tumor, target, and normal tissues on a slice-by-slice basis, and, at the same time, view the contours on planar images from both AP and lateral projections. In addition, improved edit functions allow the user to move, scale, and rotate a contour in addition to providing tools for rapid corrections, changing the shape of a contour, automatic adjusting of a copied contour to fit a new organ boundary, and copying to inferior and superior slices. However, while advances in software for the contouring task have been made, continued improvement is still needed (particularly automated image segmentation) to increase the.
efficiency of CT-simulation/3-D planning. CT-simulation treatment planning can take minutes or hours, depending upon the complexity desired. Stephenson and Wiley indicate that the average length of CT-simulation is less than 1 hour, including patient positioning, CT data acquisition with an average of 40 cuts, physician contouring of target volume, volume of interest or isocenter definition, and the projection of the isocenter on the patient. They correctly point out that the amount of time the patient spends on the CT table is less than with conventional simulators for most sites. This is because beam angles and portal apertures can be determined after the patient has left the simulation room as long as sufficient fiducial reference marks are made on the patient’s skin and immobilization device to allow precise repositioning at the treatment machine. However, the reader is warned that care must be taken to avoid the selection of beam directions that are untreatable because of complex treatment geometry (ie, incompatible table and gantry rotations). Developers of CT-simulation/3-D planning software are encouraged to implement collision avoidance features in future software releases.

Application to Prostate Imaging
The authors emphasize their use of CT urethrography in improving the definition of the prostate target volume. This is an important point, as the appropriate use of CT contrast agents is not something most radiation oncologist are familiar with, and can be of significant value in delineating tumor volume and normal tissue contours. However, the authors fail to mention the importance of multimodality (eg, MRI, SPECT, etc.) imaging in accomplishing this task [8]. No doubt this is because image correlation software is just now becoming part of the CT-simulation/3-D planning process to assist the radiation oncologist in this task. However, there is little question that such tools will prove invaluable in advancing such imaging/planning even more.

Because most radiation oncologists are unfamiliar with the definition of target volumes and normal tissue on axial CT slices, assistance from a diagnostic radiologist will likely be needed in these early years of the CT-simulation/3-D-planning era. No doubt, image-based cross-sectional anatomy training is now needed in radiation oncology residency training programs. The authors state that the CT-simulator-generated DRRs provide acceptable bone detail and anatomic agreement with port films taken on the treatment unit. They report the best quality DRRs are obtained with a non-spiral CT slice thickness of 2 mm and table increment of 2 mm, but give little detail supporting this claim. A more rigorous scientific analysis of DRR film quality is needed in the literature. No doubt, DRR quality is improved with finer slice thickness, but the reader must understand that this results in a greater workload in contouring the image data and increased equipment cost (larger capacity computer hard drive).

Data Transfer
An important area not discussed in detail by the authors is the transfer of data between the CT-simulation system and the dose planning system. Because of increased efficiency, flexibility, and low cost, computer networks have become the method of choice for communicating digital data. However, currently there is no standard for this data transfer, and oftentimes connecting the various components of a CT-simulation/planning system becomes a major obstacle for full clinical utilization. This problem is being addressed by a working group of the National Electrical Manufacturers Association (NEMA), who are working to extend the DICOM 3.0 standard [9]. Unfortunately, this standard is several years away from full implementation, so the problem remains highly relevant to new CT-simulator users. The authors discuss 3-D dose calculations and dose-volume histograms, but do not identify the source of the calculations. The Picker ACQSIM software provides no dose calculation capability. Thus, the authors' discussion on these subjects could mislead the reader.

A Major Shortcoming
A major shortcoming of the Stephenson and Wiley article is their failure to mention the ICRU-50 methodology (Prescribing, Recording, and Reporting of Photon Beam Therapy) for defining tumor and target volumes [10]. This methodology is being used in current clinical trials involving 3-D planning, and thus the reader interested in CT-simulation/3-D planning should be aware of this approach in defining target volumes. This author hopes that the radiation oncology community will adopt a common approach such as the ICRU 50 methodology, which should allow institutions throughout the world to share more easily their results and clearly help CT-simulation/3-D treatment planning progress in a most efficient manner.

CT-Simulation/3-D Planning Process Likely to Grow
The era of CT-simulation/3-D planning is now beginning in earnest. University developed prototype systems are being replaced by robust commercial systems that are full-featured and easy to use. There is clear advantage to CT-simulation/3-D planning in better defining tumor/target volumes and
the display of the defined target volumes and critical structures on DRRs. This facilitates optimal beam projections and determination of treatment apertures to maximize target volume coverage and minimize treatment of adjacent tissues. The next step is to show that this advantage leads to improved outcome, so clinical trials are imperative.

CT-simulation/3-D planning also offers other practical advantages that are often overlooked. First, patient satisfaction is clearly improved, since the virtual simulation process reduces patient fatigue and frustration during the planning process. Also, in the long run, when fully developed, this integrated 3-D technology will lead to improved efficiency of planning, delivery, and verification, and thus, lower costs.

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