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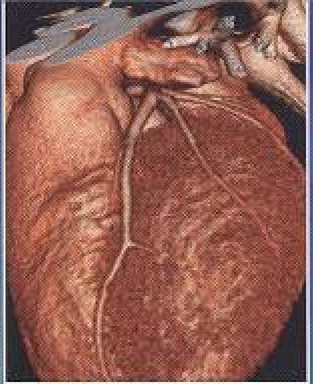
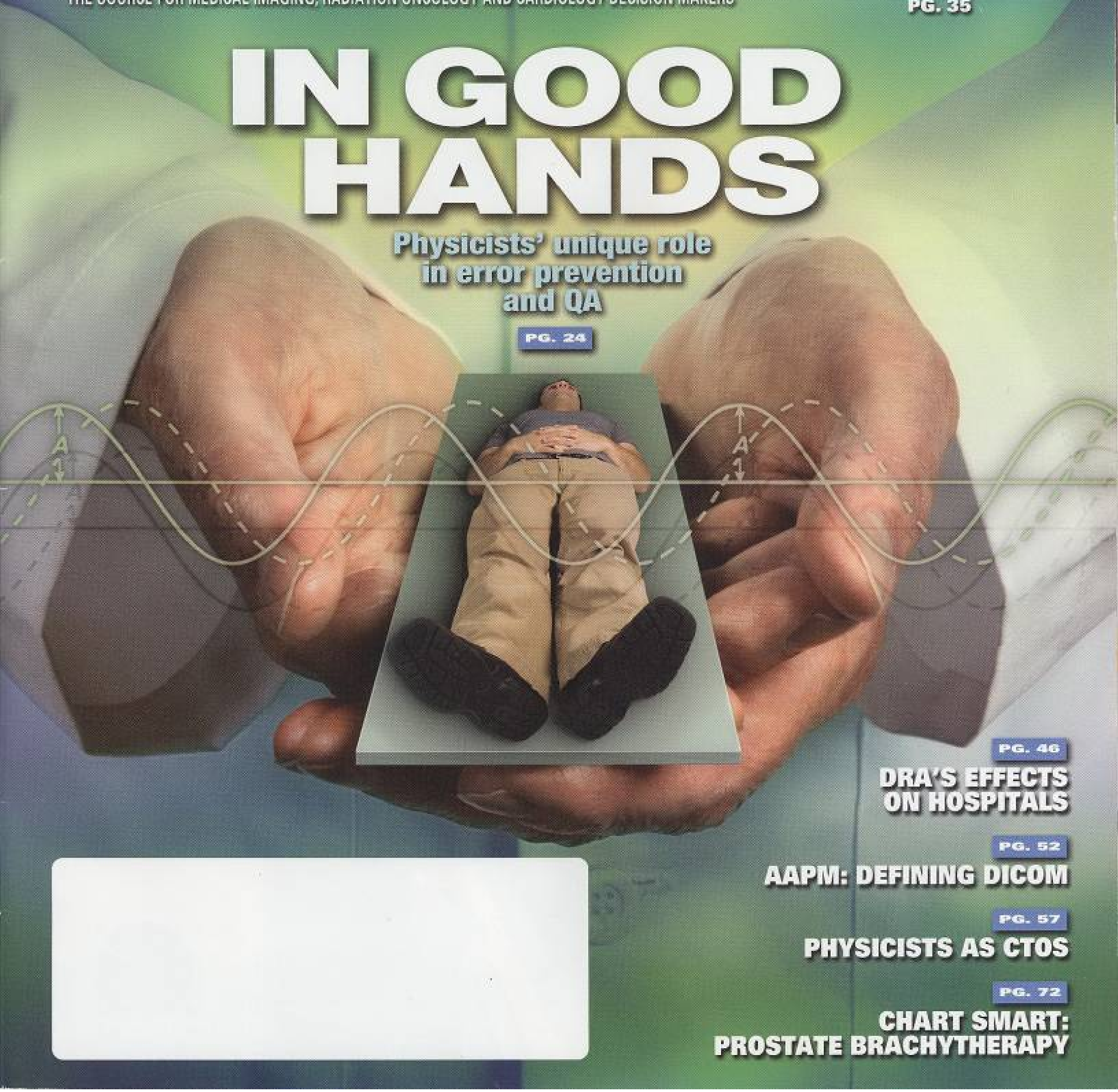


CTA'S TRIPLE RULE-OUT
PG. 35

IN GOOD HANDS

Physicists' unique role in error prevention and QA

PG. 24



PG. 46
DRA'S EFFECTS ON HOSPITALS

PG. 52
AAPM: DEFINING DICOM

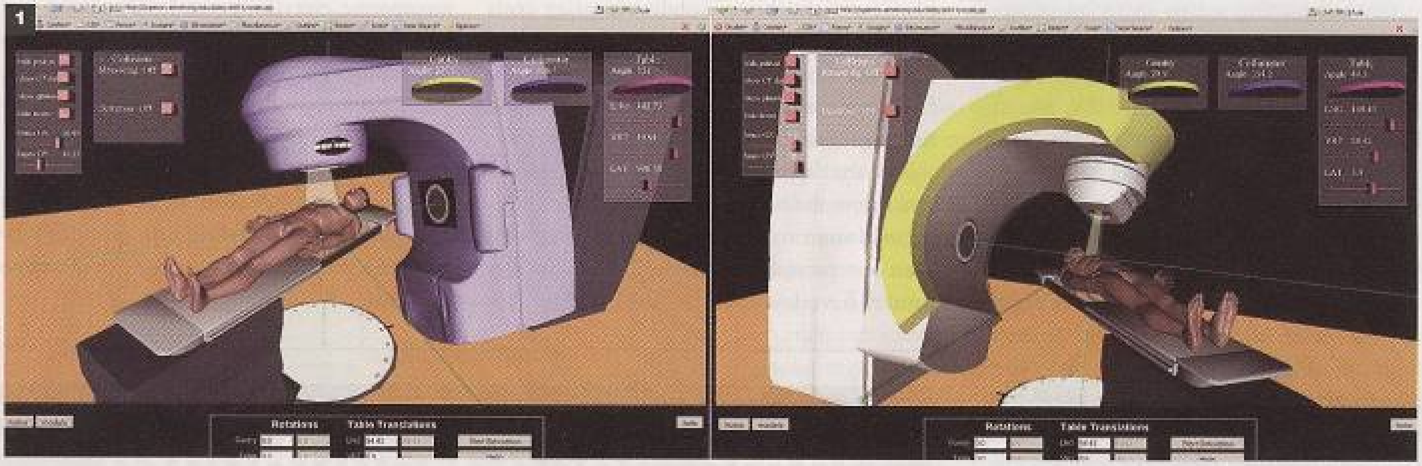
PG. 57
PHYSICISTS AS CTOS

PG. 72
CHART SMART: PROSTATE BRACHYTHERAPY

COLLISION DETECTION

AN INTERDISCIPLINARY RESEARCH TEAM DEVELOPS A NOVEL 3-D WEB-BASED SIMULATION AND TRAINING SYSTEM FOR RADIATION ONCOLOGY.

BY FELIX HAMZA-LUP, PHD, IVAN SOPIN AND OMAR ZEIDAN, PHD



While radiation therapy is an effective cancer treatment, its maximum efficacy hinges on the abilities of the medical professionals who use it. The interplay between different hardware components of external-beam radiation therapy (EBRT) linacs is rather complex and hard to visualize during the computerized treatment planning. In addition, the ▶

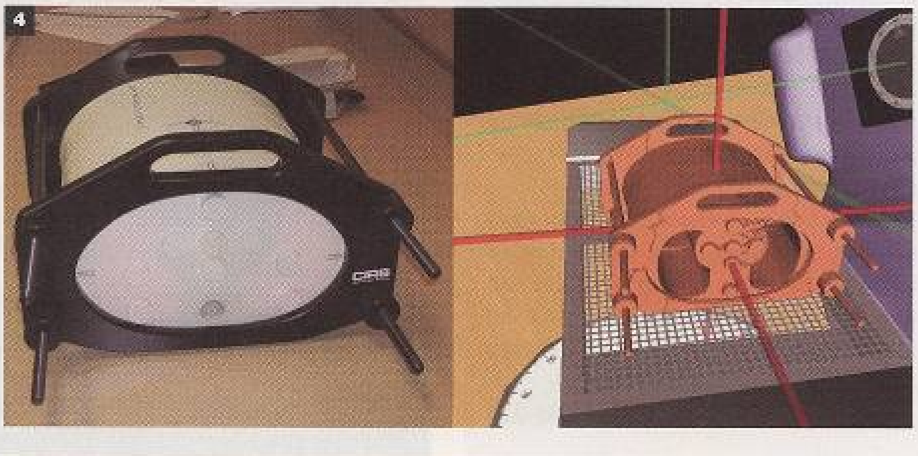


FIGURE 1. Graphical simulators for Varian 23iX (left) and Varian 600N (right). **FIGURE 2.** Measuring tool (as the user moves the red/blue dots in the virtual space, the distance between them is displayed on the screen). **FIGURE 3.** No collision (left) and collision (right) scenarios. **FIGURE 4.** A quality assurance phantom device: physical (left) and modeled (right). The red orthogonal axes mark the locations of the surface fiducials (BBs). *images/ courtesy Dr. Hamza-Lup*

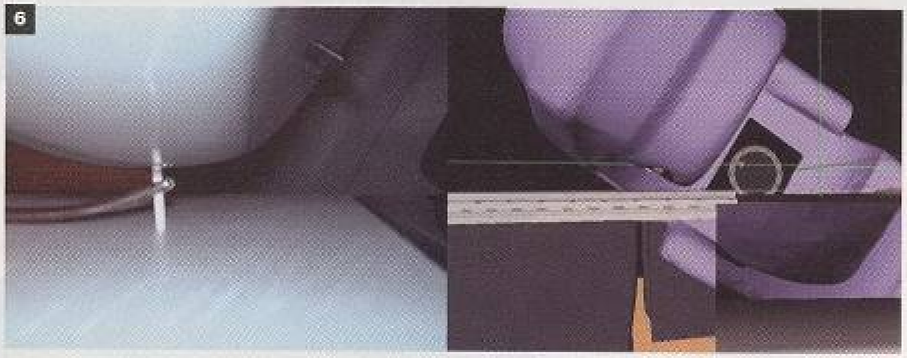


FIGURE 5. **The grid table surface (top: virtual; bottom: real).**

FIGURE 6. **Visual collision validation of a 5 mm surface-to-surface separation: the real linac (left) using a 5 mm spacer and the simulator (right).**

lack of collision detection (CD) on available treatment planning software burdens the planner with the challenge of creating a collision-free plan.

Solution at work

Our research team has proposed a 3-D graphical simulator for linacs that will save time and resources in generating the optimal treatment plan while simultaneously serving as a learning tool. Embedding patient-specific data such as computed tomography (CT) scans in the interactive simulator advances the radiation therapy planning process by detecting collision cases earlier. The Web-based interface helps visualize the behavior of the linac components and detect collisions during planning. The simulator components follow the actual hardware motion and angle conventions, and are controllable individually using a mouse or a keyboard, which enables the user to enter specific values. The simulator allows easy identification of the beam-table intersections by modeling the radiation beam as a prism of light projected at the isocenter and collimated to match the beam geometry.

Several investigators[1-4] proposed a variety of analytical and graphics-based CD tools for solving the collision problem in EBRT. However, the graphical solutions were highly inaccurate as they were based on manual measurements of linac components. Furthermore, analytical tools are difficult to implement since they involve complicated trigonometric relations that require precise linac dimensions. Also, because these tools employ only generic patient models, potential patient-specific collisions cannot be predicted.[5]

- *3.1 Methods.* Using this approach, the simulator implementation takes advantage of X3D,[6] a real-time 3-D computer graphics standard, and several 3-D modeling software tools at the development stage. Figure 1 is a snapshot of the virtual room (denoted 3-D radiation therapy treatment, or 3DRTT), which models the real environment.
- *3.2 GUI.* Here, the simulator provides an intuitive floating graphical user interface for controlling the angles and locations of the machine's part (Figure 1). This GUI appears in the form of multiple semitransparent windows containing various volumetric controls. Segregating the controls into semantically logical groups (the scrolls for rotations, slides for translations and buttons for switching between different simulation modes) improves the human-computer interaction. The user can easily rearrange the GUI components to avoid occlusions of important objects.

The measuring mode (Figure 2) enables the user to estimate the exact distance between any two points in the virtual space. These measurements

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are useful for simulation assessment and in collision scenarios, when spatial misinterpretation is possible.

The CD mode (Figure 3) activates an automatic collision warning system to guard for the user's potential misinterpretation of the visual collision scenario. The CD system is based on bounding primitives and uses an algorithm optimized to work in a Web-based environment. The CD accounts for collisions between the gantry and the table, alerting the therapist to any small clearance case. The measuring tool can be used to obtain accurate measurements following a collision warning.

An additional menu allows the user to visualize 3-D patient data on the table. Digital Imaging and Communication in Medicine Radiation Therapy (DICOM RT) CT data scans[7] and phantom devices (Figure 4) are used by therapists for testing purposes. The user can enable the beam projected by the collimator and control the size of the beam spot with graphical sliders.

- *3.3 Polygonal models.* To collect point clouds from several viewpoints, we use laser scanners. We merge the cloud points, filter the noise and wrap the valid points into a polygonal model. Due to scanner inaccuracies (approximately 3 mm), we smooth the 3-D objects; and to improve the rendering process, we apply a decimation algorithm and remove redundant polygons in flat areas. The polygonal model is exported into an X3D object and employed as part of the virtual scene. We optimize the scene such that adequate frame rates (25 frames per second or higher) are obtained on machines with low rendering power.

To further improve rendering speed and reduce file size, we use textures to simulate the geometry of complex areas. Some cases might call for special processing. For instance, the table contains a special glass-like component. Because this material doesn't attenuate the beam in reality, we tune the transparency of the detail's surface to resemble the glass and combine it with a translucent cellular texture laid underneath (Figure 5).

Results

To improve the features and functionality of the simulator, we have deployed a prototype on a secure Web site (*http://hyperion.armstrong.edu:8080/3DRTT*) equipped with an access and feedback mechanism. Users from several medical institutions have registered on the site, and are evaluating the prototype and providing feedback.

To objectively test collision scenarios, we asked radiation therapy technicians and therapists to simulate treatment plans that contain collisions among the system components (Figure 6). The simulator provides an accurate representation of the linac and can predict collision scenarios with 5-mm accuracy based on preliminary assessment results.

This EBRT treatment simulator could be used for treatment planning validation of patient-specific collision scenarios and beam-table CD once its clinical validation is approved. It is Web-based and, therefore, software-platform-independent. The ability to predict a possible collision between all linac components for a given patient eliminates the need for backup plans and saves planning time. It also enables the planner to explore differing and unconventional gantry-table-collimator combinations for treatment that may give rise to better quality plans. ■

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