

LETTER TO THE EDITOR

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# Response to “in regard to “Tran A, Zhang J, Woods K, Yu V, Nguyen D, Gustafson G, Rosen L, Sheng K. Treatment planning comparison of IMPT, VMAT and $4\pi$ radiotherapy for prostate cases””

Ke Sheng

## Abstract

In regard to our recently published paper entitled “Treatment planning comparison of IMPT, VMAT and  $4\pi$  radiotherapy for prostate cases”, a question was raised whether “ $4\pi$ ” was used appropriately to describe the non-coplanar planning and delivery space. In this letter, the term use is explained from both theoretical and practical perspectives. It is concluded that the self-explanatory term provides a flexible description of non-coplanar radiotherapy with beam orientation optimization. Confusions with this term can be avoided by understanding the evolving and machine/patient specific nature of  $4\pi$  planning,

**Keywords:**  $4\pi$ , Non-coplanar radiotherapy, Treatment planning, Optimization

## Letter to the Editor:

Recently, Dr. Sarkar questioned our use of “ $4\pi$ ” to describe non-coplanar external beam radiotherapy. This discussion brought the much needed attention to this topic. However, I disagree with his conclusion that  $4\pi$  should not be used to describe non-coplanar radiotherapy for the following reasons.

1. Dr. Sarkar’s assessment of the solid angles is mathematically incorrect. Without considering collision, Dr. Sarkar estimated the theoretical accessible solid angles based on the observation for a typical C-arm linac that the gantry has  $360^\circ$  access while the couch only has  $180^\circ$  access. The observation is correct but Dr. Sarkar neglected the symmetry of the C-arm gantry geometry and the additional freedom of combining the gantry and couch rotation. In fact, the couch only needs  $180^\circ$  rotation to provide the full  $4\pi$  access. Figure 1 shows such a complete surface for a theoretical  $4\pi$

treatment. One can visualize how the entire  $4\pi$  solid angle is covered with the combination of  $180^\circ$  couch and  $360^\circ$  gantry rotation.

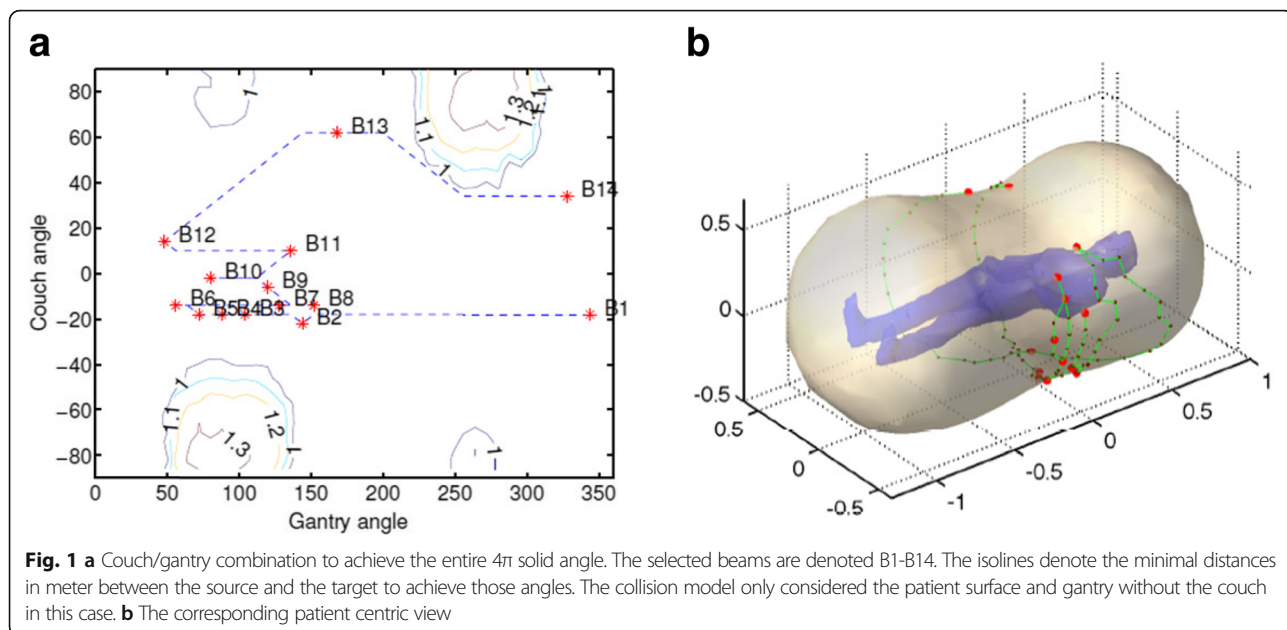
2. Even with the collision consideration, the angles that can be safely accessed for head or foot treatment is significantly larger than a hemisphere. One can consider a typical brain treatment where not only the superior angles are accessible, some of the inferior oblique angles are also available by rotating the gantry towards the patient torso while the couch is rotated. It is true that the solid angle for body treatment is more limited such as the left lung treatment shown in Fig 2a. When the source-to-isocenter distance is limited to 100 cm, the feasible angles shown in Fig 2c is limited. However, the accessible non-coplanar beam angles can be expanded by allowing source-to-isocenter distances greater than 100 cm. An example is shown in Fig. 2b using the validated geometrical modeling method described previously [1]. With the extended distances, approximately 70% of the  $4\pi$  surfaces are covered for a left lung treatment. Note that a

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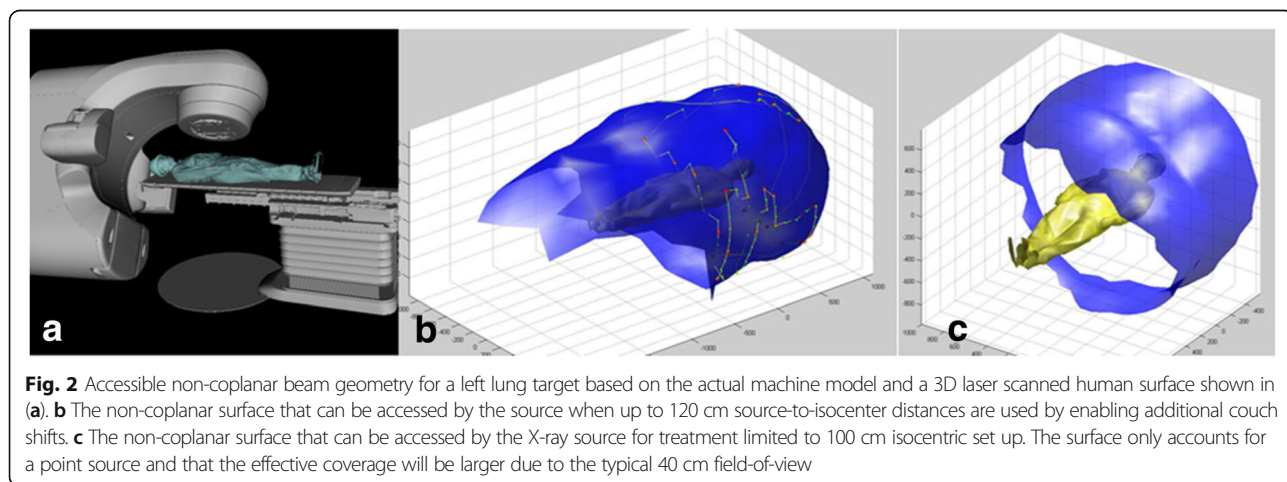


portion of the missing non-coplanar surface is caused by the couch pedestal occlusion.

3. Dr. Sarkar calculated the spherical surface covered by a 40 cm × 40 cm field in a 360° arc. He then argued that the actual solid angle is much smaller due to the smaller actual field sizes. This is a misunderstanding of  $4\pi$  treatment planning, which indicates the freedom of *selecting* beams from the  $4\pi$  solid angles instead of *using all* beams in a single plan.
4. There is a benefit of keeping  $4\pi$  as an open software and hardware platform to encourage and incorporate future development. The mechanical restrictions to approach  $4\pi$  solid angles are neither insurmountable nor static. Extended source-to-isocenter distances are readily achievable with existing C-arm platforms, although additional quality assurance and

commissioning may be needed to safely use this mode. Robotic couches that are being introduced in the radiation oncology clinic [2] will certainly further expand the non-coplanar angle access if not enabling the full  $4\pi$  solid angles. CyberKnife has limited posterior beam access but nothing fundamental prevents the next generation robotic linacs to gain access these angles.

5. Finally, there is a beauty in the nomenclature.  $4\pi$  is not a typical undecipherable acronym that one has to look up. It is simple yet self-explanatory. Different from the conventional term of “non-coplanar radiotherapy”, it emphasizes the ability of automated beam orientation optimization in the non-coplanar solution space. It reflects continuously evolving effort in planning algorithms and delivery platforms advance radiotherapy dosimetry.



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**Availability of data and supporting materials**

Please contact author for data requests.

**Author's contribution**

KS conceived of, drafted, revised and approved the letter.

**Ethics approval and consent to participate**

The study is approved by UCLA Internal Review Board (IRB) #12–001882.

**Consent for publication**

The letter shows the surfaces of a human subject (the author), who agrees to the publication of the letter.

**Competing interests**

The author declares that he has no competing interests.

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