Integrating 3D Rotational Angiography into Gamma Knife Planning

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ABSTRACT
SUMMARY: 3D rotational angiography provides remarkable spatial resolution for cerebrovascular disorders; however, it cannot be integrated directly into gamma knife planning due to the discrepancy of DICOM “tag” information, and most physicians still cannot benefit from 3D rotational angiography. Here, we describe a simple and easy technique to enable the integration of 3D rotational angiography.

ABBREVIATIONS: GKRS = gamma knife stereotactic radiosurgery; 3DRA = 3D rotational angiography

Gamma knife stereotactic radiosurgery (GKRS) is an image-guided radiation therapy characterized by its high geometric accuracy; thus, no treatment margin is usually required when circumscripting the target. This feature, in conjunction with its sharp dose fall-off, enables high-dose irradiation in a single session; however, successful radiosurgery is highly dependent on the quality of radiographic images used.

GKRS has been accepted as one of the standard therapeutic modalities for small-to-medium arteriovenous malformations. Currently, biplanar DSA and CT angiography or MR imaging or both are commonly used in most institutions. Recently, advances in modern endovascular suites and newer generation flat panel detectors with C-arm systems have enabled acquisition of 3D rotational angiography (3DRA), providing remarkable spatial resolution for cerebrovascular disorders. Indeed, 3DRA is beginning to be used in the treatment planning of other modalities of stereotactic radiation therapy, including CyberKnife (Accuray, Sunnyvale, California), XKnife (Integra LifeSciences, Plainsboro, New Jersey), and Trilogy (Varian Medical Systems, Palo Alto, California), contributing to improved accuracy of the treatment planning.

One remaining issue is that 3DRA cannot be integrated directly into GKRS planning because the planning software (Leksell GammaPlan; Elekta Instruments, Stockholm, Sweden) does not accept 3DRA. Moreover, very few studies have described the effectiveness of 3DRA on GKRS planning, though they do not state a detailed integration method. Thus, most physicians still cannot benefit from 3DRA. Here, we show a very simple method to integrate 3DRA into GKRS planning.

Techniques
Before the day of treatment, we usually perform MR imaging (mainly time-of-flight MR angiography, supplemented by T2 and gadolinium-enhanced T1 images) for preplanning. As in the usual preparations for GKRS, the Leksell frame (Elekta Instruments) is set on the patient’s head with the patient under sedation with local anesthesia. Then, the patient is transferred to the angiographic suite (Allura Xper FD20/10; Philips Healthcare, Best, Netherlands). Along with conventional DSA, 3DRA is acquired using the programmed acquisition protocol (3DRA mode). The amount of contrast medium used and preinjection delay are individually determined by neuroendovascular surgeons; briefly, 1–3 mL/s of contrast medium is continuously injected with a 1.5- to 2.0-second preinjection delay during the rotation of the C-arm. Because 3DRA could be easily coregistered to stereotactic CT if 3DRA contained enough bony tissue, a large-sized detector is generally preferred for precise image coregistration (Fig 1A). On the contrary, the smallest 8-inch detector could be used when the nidus is located near the skull base (basal ganglia, posterior fossa, and so forth) because acquired images spontaneously contain a large portion of bony tissues (Fig 1B). The obtained volume dataset is automatically transferred to the preinstalled workstation (XtraVision; Philips Healthcare), with which further reconstruction is performed with a 256³- or 512³-resolution voxel matrix in a
By means of high-definition images, physicians can not\thave resolution with a long acquisition time (20 seconds),\nusing a\nangiographic suite. This acquisition mode provides superior spa-
tion XperCT mode; Philips Healthcare) is also available in our\nenhanced conebeam CT with a small targeted FOV (high-resolu-
tion).

Further examined. A step-by-step instruction manual to integrate\n3DRA is shown in On-line Figure. Detailed case illustrations are\nshown in Fig 2.

**DISCUSSION**

With the above-described simple contrivance, 3DRA can readily\nbe used for GKRS planning. The strength of this technique is its\naccessibility. GammaPlan cannot directly accept 3DRA because of\nthe discrepancy of DICOM tag information; accordingly, we must\naddress this issue. No changes are required in the geometric or\npatient information; thus, the image quality itself is intact.\nBecause 3DRA is a CT-like image, being characteristic of the finest\nspatial resolution for high-contrast objects with poor contrast res-
olution and thus having many features common to CT,\nste
troactic CT would be the best reference image for the coregistra-
tion. A step-by-step instruction manual to integrate 3DRA is\nshown in On-line Figure. Detailed case illustrations are shown in\nFig 2.

Although 3DRA provides superior resolution for angio-
architectures of vascular lesions, we recommend creating ra-
dius planning. Further research is desirable to examine the coregistration\naccuracy to ensure the\nquality of the prescription of the therapeutic radiation dose.

Moreover, when a nidus receives blood flow from >2 ves-
sels, the precise nidus contour is shown as the summation of\nparts of the nidus obtained by cannulation in each vessel. Thus,\nitis quite important to perform 3- or 4-vessel angiography and\njudge the involvement to avoid underestimation of the whole\nnidus angioarchitecture.

We describe a simple, easy-to-access technique to enable inte-
gration of 3DRA into GKRS planning, which could provide the\nhighest resolution for angioarchitectures of vascular lesions.\nThe present method remains preliminary; thus, the created\ntreatment plans should be validated in comparison with the\nconventional planning method. Further research is desirable to\nassess the effect of this technique on the actual radiosurgical\noutcomes.

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FIG 2. A 34-year-old woman with an unruptured, small, left medial frontal arteriovenous malformation, once treated with gamma knife (A). The small remnant nidus persisted at 3.5 years from the initial radiosurgery (B, a red arrowhead shows the remnant nidus). The actual treatment planning of the secondary treatment (C) shows that 3D rotational angiography (left column) successfully depicts the faint remnant, while both time-of-flight (middle column) and gadolinium-enhanced T1 images (right column) fail to depict it. The nidus was finally obliterated (D) at 15 years from the secondary treatment. Yellow lines show the prescription isodose lines.

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