Letter to the Editor

CT cinematic rendering for glomus jugulare tumor with intracranial extension

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Introduction

The development of multislice computed tomography (CT) scanners able to acquire high-resolution isotropic volumetric datasets has paved the way for the elaboration of three-dimensional (3D) CT images into clinical practice. Currently, both maximum intensity projection (MIP) and volume rendering (VR) methods are commonly used as adjuncts to axial images and multiplanar reformations (MPR) in cases of complex anatomy and physiology (1).

Recently the cinematic rendering (CR) has been developed, firstly inspired by the entertainment industry to increase the quality of computer animation programs in cinema, and following used in biomedical fields to generate more photorealistic representations of the human body from CT and magnetic resonance imaging (MRI) datasets.

Differently from VR ray casting methods in which each pixel is formed by one light ray, CR introduces a new paradigm, enabled by recent advances in computer graphics, in order to render volumetric medical image data by using a physically based real-time technique.

As a result, the technique models the real-life physical propagation of light, creating complex lighting effects, such as shadows, subsurface scattering, refraction, depth of field, absorption, and ambient occlusion. The CR makes use of these techniques to produce photorealistic images (2).

CR images contain high levels of detail with shadowing and depth that are not available from traditional 3D CT techniques (3,4).

The following case report outlines the advantages of the new rendering method in a patient with glomus jugulare tumor (chemodectoma), supporting CR as a potential post-processing tool to improve diagnosis and treatment planning (5).

Case presentation

A male patient, age 61, presented symptoms of right ear hearing loss, difficulty swallowing and persistent cervical pain. The subject was a smoker, non-allergic and without cancer familiarity. During clinical history collection the patient previously reported:

- An otorhinolaryngologist visit, due to persistent dysphonia and dysphagia since a month. The specialist reported a slight hypertrophy of the right lingual margin, paresis of the laryngeal right true cord with minimal salivary stagnation in the right pyriform sinus. At the swallowing test, pre-swallowing falls with minimal penetration and stagnation in the right pyriform sinus.
- A doppler ultrasound (US) of the epiaortic vessels detecting a diffuse thickening of the carotids, without hemodynamically significant stenosis.
- A brain MRI, identifying a mass-like alteration in the skull base (size 23×19 mm in the axial plane), showing intermediate signal in T2, hypointense in T1 and intermediate in diffusion-weighted imaging (DWI) with contextual small areas of signal lack suggestive for vascular structures. This lesion extends inferiorly to the jugular foramen until the right infratemporal fossa, posteriorly to the right carotid, for a longitudinal size of about 50 mm, developing closely to the sigmoid venous sinus and the surrounding bony structures. Right mastoiditis was also reported.

The patient performed at SDN research institute a Dual-Energy CT (DECT) exam of the head and neck district with contrast agent injection, in order to deeply evaluate bone remodeling and vascular involvement (6). The imaging scan was performed using a Siemens SOMATOM Force 384-slice CT dual source scanner (Siemens Healthineers, Erlangen, Germany) using a standard clinical CT protocol (Care kV with reference 90/150 kVp; CareDose with 100/70 reference mAs; 2×192×0.6 mm collimation). An additional tin filter (Sn) was added to the 150-kV beam to increase spectral resolution.

At first, a non-contrast scan of the brain was performed for evaluation of bone involvement. Following, 50 mL of iodinated contrast agent (Iopamiro 370 mg/mL, Iopamidol, Bracco, Italy) were administered via power injection into peripheral intravenous line at a rate of 4 cc/second. Dual energy angiographic scanning, was performed immediately after pre monitoring, including from the aortic arch to the Willis' polygon with a thickness of 0.6 mm, at X-ray tube potentials of 90 and 150 kV (with additional Sn filter). Further dual energy scanning was performed 60 seconds after the injection for the evaluation of the venous system. Finally, a post contrast brain scan was achieved. Total dose length product (DLP): 2,710 mGy × cm.

Images were analyzed using the 3-material decomposition algorithm of the DECT software (syngo.via Dual Energy, Siemens Healthineers, Erlangen, Germany) with "bone removal" workflow, in coronal and sagittal planes with both MPR and MIP reconstructions (7).

To support radiological workflow and potentially surgical planning, 3D views of the lesion were created, including both traditional VR and CR, using Siemens Syngo VB-30 workstation (Siemens Healthineers, Erlangen, Germany) (8) (*Figure 1*).

Lesion extended cranially from an axial plane passing through the right styloid process apex, until the posterior cranial fossa, between the internal jugular vein, not dissociable, and the internal carotid artery (D1/2 according to Fish-Mattox classification) (9). The lesion passed through the jugular foramen, that appeared eroded such as the neighbor temporal bone, running medially to the sigmoid venous sinus, dislocated, and engaging the hypoglossal canal nerve, enlarged, and the corresponding cranial nerve.

CR extensively display tumor vascularization and the relationship with the surrounding vascular structures, also helped by different setting windows which can support presurgical planning. Moreover, compared to conventional VR, CR provides more image details, displaying a more photorealistic and vivid appearance of tumor and bone structures from different angles. Moreover, the possibility to combine CR visualization to DECT acquisition allows to maximize structures definition and differentiation, applying different windows settings and transparencies to different DECT reconstructions (e.g., after automatic bone or contrast material removal) (10).

Finally, the patient was addressed for an interventional procedure of lesion embolization.

Discussion

Glomus tumors are benign, slow-growing tumors that include cervical and temporal bone (jugulotympanic) paragangliomas. Among these categories, glomus jugulare tumor represents a particular and more rare kind of jugulotympanic lesion, often considered as surgically inaccessible for its possible intra- and extra-cranial extension (11,12).

Multiplanar diagnostic imaging, and in particular high-resolution CT, is crucial for the management and workflow of a suspected tympanic paraganglioma in order to approach differential diagnoses and to finely characterize the extension of lesion and the relationship with the surrounding structures. Bone erosion around the jugular bulb is a characteristic CT feature for this kind of tumor, considering its origin from paraganglion cells in the venous adventitia. Moreover, lower cranial nerves can be compromised by tumor growth, and hypoglossal canal invasion can occur in about 71% of cases, and appear enlarged in CT scans (13).

For all these aspects, CT imaging and its reconstructions and visualizations represent an essential step in this kind of patients. Recently, CR has been proposed for complex anatomy representation, providing a more natural and photorealistic visualization of CT image data, with an improved depth and shape perception compared to VR. The applications of CR are numerous and varied, including medical education, easy disease detection, and better description and classification of lesions. Recently, examples of CR advantages in the context of musculoskeletal trauma and chest cardiovascular pathologies have been presented and qualitatively compared to other 3D post-processing methods (14,15). Moreover, realistic shadowing effects and different windowing are likely to find more approval in surgical and procedural guidance (16).

In this case, both 3D visualization methods were used to display the full extent of the tumor and contextualize the

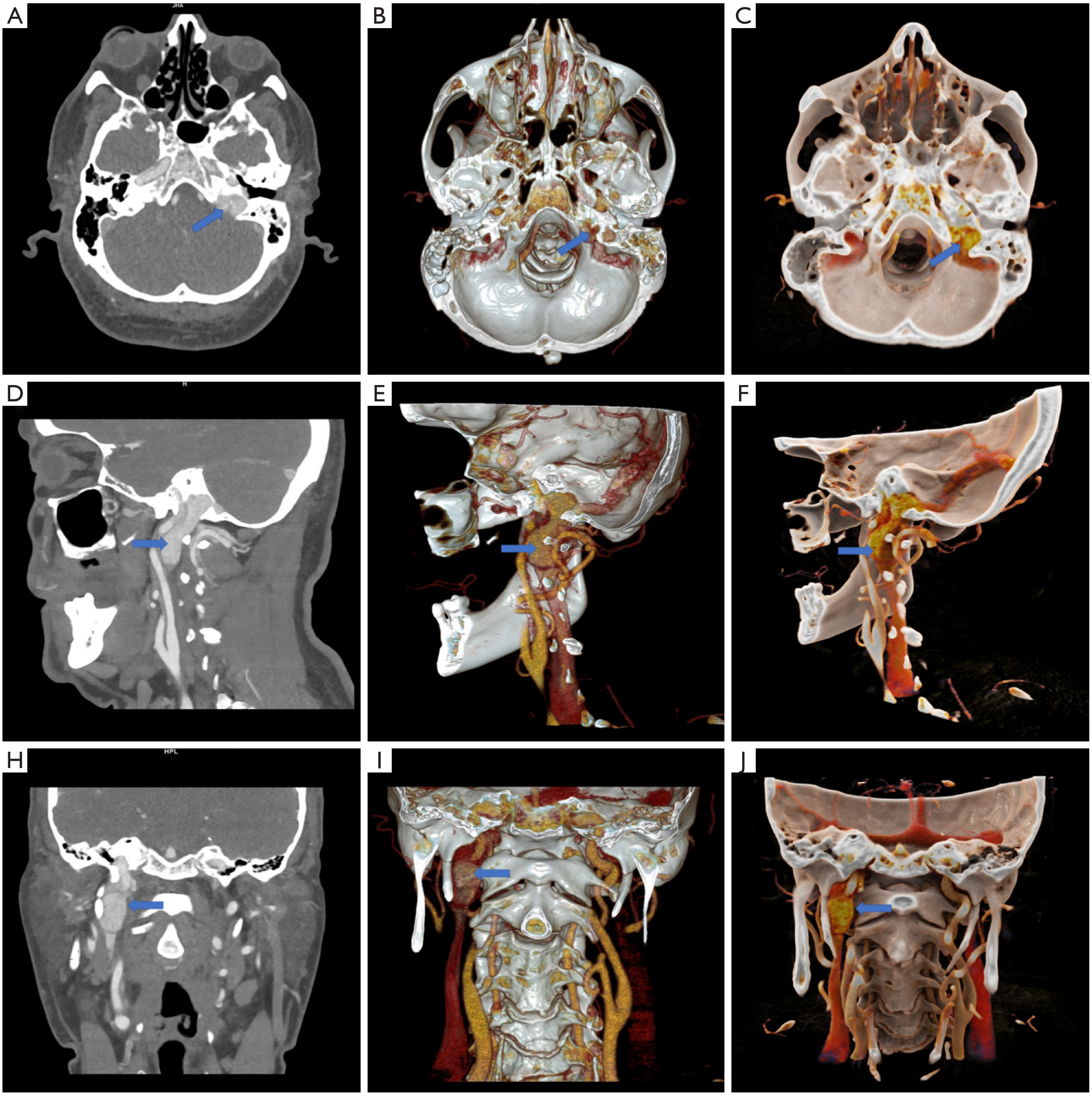

Figure 1 Contrast-enhanced 3D images of a glomus jugulare tumor with intracranial extension. (A,D,G) MPR reconstructions, respectively in the axial (anatomical view), sagittal and coronal planes showing the lesion (blue arrows); (B,E,H) VR images; (C,F,I) CR images where high contrast structures such as vessels and bones are well represented; (F,I) images show more contrast and better sense of wound depth. Moreover, compared to axial image (A) and VR image (B), the CR (C) allows a better visualization of the bony erosion (blue arrows). 3D, three-dimensional; MPR, multiplanar reformations; VR, volume rendering; CR, cinematic rendering.

tumor within the complex anatomy of the facial structures and the skull's base.

CR technique has been used to create photorealistic visualizations from standard volumetric CT data, displaying high levels of anatomical details in a region of complex anatomy and pathology. Indeed, CR is superior to VR mainly to visualize depth and soft tissue structures, not otherwise easily rendered (17). By adjusting the window width and level settings during the interactive process of CR image creation, the radiologist or radiographer is able to add or subtract overlying layers of soft tissue so that various aspects of a pathologic process or complex anatomy can be displayed, and a realistic virtual dissection can be mimicked. As with VR, CR can provide information on different tissue types by adjusting the display parameters to better visualize soft tissues *vs*. higher attenuating objects. The shadowing in CR can improve anatomical understanding in regions of complex anatomy, particularly with overlying or overhanging structures, although the prospective view can partially hidden deeper regions. In fact, while traditional VR considers each reconstructed voxel as independent, CR displays neighboring voxels in an interactive manner, adapting light and shadow conditions in a panoramic view. Moreover, beyond shadowing, the CR global lighting model is well suited to displaying small anatomical structures due to intrinsic very high surface detail: a feature that can be used to resolve for example small vessels within the matrix of tumor neovascularity. Anatomical differentiation can be also improved by DECT protocols that using an apriori separation of many tissues, assured by a different setting of the radiogenic tube, can maximize structures definition, open new possibilities for ad hoc filters, windows settings and transparencies.

CR limitations are based on the limited availability of the system and high costs due to the hardware requirements. Instead, VR techniques carry the risk of under- or over-estimating small pathologies with Hounsfield values resembling the neighboring tissues. Therefore, CR serves as an add-on tool to enhance visual understanding of CT data.

Conclusions

In conclusion, we reported a rare case of glomus jugulare tumor, characterized by DECT and represented in a comparative CR *vs*. VR manner. The superior anatomical detail and prospective view of CR were highlighted in a so complex pathological condition characterized by a high concentration of very different structures.

Acknowledgments

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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