Research Article

The Journal of Hepatology

The usefulness of the cinematic volume rendering method: malignancies connected to the brachial plexus can be identified using magnetic resonance imaging.

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Received Date : June 07, 2024
Accepted Date : June 09, 2024
Published Date : July 09, 2024

ABSTRACT

Overarching Goal to investigate the diagnostic benefits and clinical utility of the cinematic volume rendering method (cVRT) in assessing the connection between the blood arteries, peripheral tumor lesions, and the brachial plexus.
Supplies and techniques We included in our analysis 79 individuals diagnosed with brachial plexus malignancies between November 2012 and July 2022. T1WI, T2WI, 3D-STIR-SPACE (3D-short recovery time reversal recovery fast spin-echo imaging), and the T1WI enhancement sequence were performed on each patient. Additionally, a three-dimensional model that accurately depicted the position and tissue structure of the tumor and the brachial plexus nerves in all directions was rendered and obtained using cVRT.
Outcomes : The study comprised 71 patients (mean age, 47.1 years; 33 males, 38 females) with brachial plexus-related malignancies. Using cVRT, the brachial plexus nerve, the vascular architecture of each patient, and the surrounding tumor lesions were all clearly visible. 37 patients had unilateral or bilateral growths along the brachial plexus nerve that were fusiform, spherical, or multiple-beaded; seven patients had tumors that pushed against the nerve and had irregular, circular, or lobular morphology; sixteen patients had spherical tumors that encircled the nerve; and eleven patients had tumors that invaded the nerve and had irregular morphology. On T1WI, the mass exhibits a rather consistent or uneven signal; on T2WI, it displays a high or mixed signal.
The signal was either uniformly or unevenly boosted after enhancement.
Conclusions : cVRT reliably provided information for clinical diagnosis and therapy by clearly demonstrating the origin of tumors connected with the brachial plexus and their interaction with the nerves and peripheral blood vessels.

Keywords : Brachial plexus nerve, Tumor, Blood vessels, Cinematic volume rendering technique (cVRT)

INTRODUCTION

The intricate anatomical structure known as the brachial plexus innervates the upper limbs, shoulders, and upper chest. A brachial plexus injury can seriously impair a patient's limb, cause a partial or total loss of upper limb function, or possibly result in a permanent handicap [1]. The function of the brachial plexus nerve may be affected by nearby malignant tumors. The incidence of tumors in the brachial plexus nerve area in upper limb malignancies is roughly 1-4.9% [2, 3], with benign tumors making up 76.9-91.6% of these cases [4, 5]. The most effective way to treat tumors surrounding the brachial plexus is surgical excision. The tumor's size, growth place, and biological characteristics all have a significant impact on the clinical treatment plan for the patient.
Therefore, it is crucial for doctors to determine the tumor's location and qualitative diagnosis prior to surgery.
High-tissue contrast is a characteristic of magnetic resonance imaging. Therefore, it is the most effective noninvasive examination technique for identifying cancer of the brachial plexus [6–8]. With the increasing use of magnetic resonance brachial plexus neuroimaging in recent years, there has been an increased focus on imaging research for cancers associated

to the brachial plexus.

In order to direct surgical techniques and assess resection ability, brachial plexus neuroimaging can precisely characterize the imaging features of tumors connected to the brachial plexus, such as the lesion size, location, source, and surrounding tissue involvement [9].

The 3D-STIR-SPACE sequence inhibits background fat in order to properly display the brachial plexus.

This sequence can also reveal the location, genesis, and extent of malignancies connected to the brachial plexus. Through post-processing, it is possible to recreate it in three dimensions, which makes the spatial position relationship between the tumor and the brachial plexus evident. Nevertheless, there are several restrictions on how the 3D-STIR-SPACE sequence can depict how cancers are encircling and invading the brachial plexus. The principles of Volume Rendering (VR), which entails integrating high-resolution volumetric data from medical pictures to generate a 3D depiction of an object's internal structure, are expanded upon by the cinematic volume rendering technique (cVRT) [10].

Our goal in this study was to better illustrate the relationship between cancers associated with the brachial plexus and the plexus itself by using cVRT to merge the brachial plexus with surrounding tumor lesions and vascular anatomy in three dimensions. Furthermore, our goal was to offer more accurate and user-friendly image data for medical applications.

MATERIALS AND PROCEDURES

Participants in the study

At our institution, 79 individuals with malignant lesions connected to the brachial plexus nerve were examined between November 2012 and July 2022. Due to insufficient magnetic resonance images, respiratory or metallic artifacts, or low picture quality, eight of these individuals were eliminated (Fig. 1). As a result, 71 patients—33 men and 38 women—were included in this investigation.

T1WI, T2WI, 3D-STIR-SPACE, and T1WI enhancement sequences were performed on each patient.

The primary clinical signs included swelling and paralysis in the upper limbs and neck, as well as tumors on the affected side of the neck and numbness in the hands. Notably, in eleven cases there were no overt signs of discomfort. Of the seventy-one patients, sixteen cases of schwannoma were confirmed clinically, nine were confirmed by tissue biopsy, and 46 were confirmed by surgery and pathology (Table 1).

To relieve the patient's psychological pressure, explain the examination procedure, and advise them of its goal and safety precautions, communication was started with the patient's family. The ethical committee of the hospital approved this study, and informed consent was given by each patient.

MRI specifications

A Siemens 3.0 T MRI scanner was used to assess each patient, and T1WI, T2WI, 3D-STIR-SPACE, and T1WI enhanced sequences were performed. The patient was put in a supine position, with the arms at his or her sides, and the head and neck lifted appropriately for the magnetic resonance imaging examination. To reduce motion artifacts, the patient also refrained from swallowing and taking heavy breaths during the procedure. The traditional method for scanning was as follows: TR=650 ms, TE=12 ms, 40 cm x 40 cm, matrix 307 x 307, and slice thickness 4 mm for T1WI; TR=3000 ms, TE=101 ms, 22 cm x 22 cm, matrix 314 x 314, and slice thickness for T2WI Using the dixon technique, 4 mm; 3D-STIR-SPAC: TR=3000 ms, TE=160 ms, field of view 42 cm ×42 cm, matrix 466 ×466, slice thickness 3 mm; T1WI-enhanced sequences with parameters identical to T1WI (Table 2).

Two minutes and thirty seconds following the intravenous injection of Gd-DTPA at a dosage of 0.2 mmol/kg using a high-pressure syringe, all individuals underwent T1WI contrast enhancement imaging. The anterior and posterior borders of the spinal canal, the upper edge of the second cervical vertebrae, and the upper edge of the second thoracic vertebrae were all included in the coronary scanning range. Furthermore, the coronary position served as a reference for the axial scans.

and the scanning range encompassed the distribution region of the first thoracic nerve root on both sides as well as the fifth cervical nerve.

Image interpretation

Two attending physicians with expertise in neuroimaging diagnosis examined every image. When there were disagreements, consultation was used to come to a decision. All patients' signal characteristics, as well as the location, size, shape, and connection of the tumor to the brachial plexus and surrounding structures, were compiled. The brachial plexus nerves were imaged using the 3D-STIR-SPACE sequence, and the pictures were sent to Siemens Healthcare's syngo.via VB40 in Erlangen, Germany, for processing. After brachial plexus MIP reconstruction To lessen interference with the anatomical positional link between the tumor and the nerves, the amount of soft tissues, including muscles, was minimized. The tumor range was sketched layer by layer after the tumor multiplanar reconstruction (MPR) was finished, the brachial plexus nerve was fused with the tumor image, and cVRT was used to render and obtain a three-dimensional model that clearly showed the location and tissue structure of the tumor in all directions as well as the brachial plexus nerves. The same technique was used to create the three-dimensional image of the blood arteries utilizing T1WI-enhanced sequences. Ultimately, the three-dimensional images of the blood arteries were combined with the three-dimensional images of the tumor and brachial plexus.

In order to enhance the observation of the correlation among the three, the blood vessel image's transparency was modified to 65%.

Outcomes

This study comprised 71 patients (mean age of 47.1 years; range of 8–79 years). Using cVRT, all patient characteristics, including the brachial plexus nerve and surrounding tumor lesions, were clearly visible. 45 patients with schwannoma, 14 with neurofbroma, 10 with metastases, 1 with astrocytoma, and 1 with mediastinal malignant neuroblastoma were among the enrolled patients.

Location of the mass

The majority of the patients had single foci in the brachial plexus, with the exception of two cases of nerve sheath tumors that displayed numerous lesions in the bilateral brachial plexus.

Thirty-five cases had brachial plexus violations on the left, while thirty-three cases involved the right. Furthermore, a case of mediastinal malignant neuroblastoma was found on the right upper mediastinal membrane, and a case of astrocytoma was found in the left armpit.

Dimensions and form of the mass

All of the lesions have maximal diameters ranging from 1 to 10 cm (mean, 4.4 cm). Of these, the tumors of 53 patients had fusiform, spherical, or numerous beaded growth along the brachial plexus nerve; the tumors of seven patients had circular, lobular, or irregular development; and the tumors of eleven patients had irregular morphology.

Features of the mass signal Forty-five schwannoma patients displayed a strong or mixed signal on T2WI and a moderately uniform or uneven signal on T1WI. Following augmentation, the signal was either uniformly or unevenly boosted, and when the mass was big, a low-signal region emerged in the center.

Equally low signal on T1WI, equally strong signal on T2WI, and unequal strengthening following augmentation were seen in 14 patients of neurofbroma. Furthermore, equal signal on T1WI, strong signal on T2WI, uniform signal, and uniform strengthening following augmentation were observed in two out of the ten cases of metastases. In one instance, the mixed signal on T2WI was somewhat higher and unevenly reinforced following amplification, while the signal on T1WI was uneven and slightly lower. A mixed high signal on T1WI and a mixed high signal on T2WI were observed in one astrocytoma patient, but no significant strengthening was observed following augmentation. Additionally, the T1WI and T2WI signals in one case of mediastinal malignant neuroblastoma were similarly low and high, respectively.

The signal was not uniform, and it did not much improve after augmentation.

Connection between the brachial plexus and the mass

Out of 45 schwannoma cases, 26 had multiple unilateral or bilateral tumors growing in a fusiform, spherical, or many-beaded pattern along the brachial plexus. Six individuals had isolated lesions surrounding and invading the brachial plexus, while thirteen patients had spherical tumors encircling and squeezing the brachial plexus. Eleven of the fourteen instances of neurofibroma had tumors lodged in the brachial plexus or growing along it in a fusiform or beaded pattern. Furthermore, the brachial plexus was surrounded and compressed by spherical tumors in three of the patients.

In one instance of astrocytoma, the brachial plexus was invaded by diffuse tumor tissue, and all of the brachial plexus's characteristic features vanished.

An excessively high signal focal point of the upper right mediastinal membrane, with hazy borders and diffuse infiltration of the right brachial plexus, was the manifestation of mediastinal malignant neuroblastoma in one case.

Seven of the ten metastasis instances had smooth-bordered, lobular, or irregular lesions with uniform signals, pressure on the brachial plexus, and smooth boundaries. On the other hand, three displayed widespread infiltration of the brachial plexus and soft tissues of the neck. Table 3 displays the MRI characteristics of the neoplastic lesions connected to the brachial plexus. The benign tumors were primarily spherical with smooth, distinct edges, as the table indicates.

In contrast, the majority of the malignant tumors had lobular shapes with uneven borders.

The brachial plexus, blood vessels, and tumor are visible in the state of the cVRT.

In terms of elucidating the origin of the tumor, the connection between the tumor and the brachial plexus, and the tumor and blood vessels, the cVRT was statistically different from the T1WI, T2WI, and 3D-STIR-SPACE sequences ($P<0.05$, Table 4). Compared to other sequences, the cVRT can provide more clarity on the tumor's origin and the relationship between the tumor, the brachial plexus, and blood vessels (Figs. 2, 3, 4).

Talk

Because of its complicated structure and superficiency, the brachial plexus nerve is prone to various diseases, injuries, and malignancies.

Therefore, for effective therapeutic treatment of brachial plexus neuropathy, precise positioning and qualitative diagnosis are crucial. Surgical excision is the most effective therapeutic therapy option for patients whose tumor lesions

affect the function of the brachial plexus nerve.
Tumors associated to the brachial plexus nerve can be found and characterized by imaging evaluation, which offers a strong clinical foundation for surgical access and selection.
First described in 1993, magnetic resonance neuroimaging (MRN) was by Fler et al. [11]. The use of this technology has progressively gained clinical recognition in applications such as background inhibition difusionweighted imaging (DWIBS) [12] and 3D-STIR-SPACE [13, 14]. The benefits of the Leiter technique are evident. It has the ability to precisely assess the compression, distortion, and interruption of postganglion nerve fibers along the whole range of the brachial plexus nerve [15].
Employing the 3D-STIR-SPACE sequence with enhanced scanning on a 3.0 T magnetic resonance scanner can help clinicians select the most appropriate course of treatment and surgical techniques, as well as clearly and intuitively demonstrate the three-dimensional display of the composition and continuity of the bilateral brachial plexus and accurately locate and diagnose tumors and other diseases involving the brachial plexus.
Studies [17] examining brachial plexus neuropathy caused by tumor compression have been undertaken using 3D-MRI technology in order to vividly and clearly illustrate the relationship between the tumor location and brachial plexus nerve. Nevertheless, this technology is still unable to effectively differentiate the brachial plexus nerve from the surrounding associated malignancies. wrapping and infiltration, hence fresh approaches to imaging or post-processing are required to offer a useful imaging guide for medical application.
The accurate physical simulation technique, known as cVRT, is based on the interplay of light and matter and allows for real-time rendering at the level of a movie. Different light interactions, such as refraction, refraction, primary scattering, and secondary scattering, are produced by using multiple light sources. The morphological perception and depth have been improved, creating a more realistic shadow that accurately depicts the anatomical level of blood vessels and soft tissues. Simultaneously, the three-dimensional analytic effect is generally more accurate and realistic, offering more precise and detailed information for clinical practice.
Hyperrealistic Rendering was used by Guo B et al. [18] to render Type II Endoleak and the three-dimensional display are more realistic and user-friendly, offering more precise recommendations and assistance for clinical preoperative assessment and boosting surgical confidence.
Surgery is typically used to remove brachial plexus nerve-related tumors completely. Before beginning any procedure, a thorough evaluation is necessary since surgery can easily injure the brachial plexus nerve [19, 20]. Therefore, following processing, a three-dimensional fusion image of the tumor, brachial plexus nerve, and blood vessels was obtained using cVRT based on 3D-SPACE-STIR brachial plexus imaging in conjunction with enhanced magnetic resonance imaging. The three tissues were distinguished using varying color levels. The spatial and positional interaction in this model between the tumor, Furthermore there was good revision of the blood vessels and brachial plexus nerve.
Of the 71 patients in this study, 25 had conservative treatment and 46 received surgical treatment. The three-dimensional fusion image produced in Case 1, a 42-year-old female patient, following cVRT therapy revealed that the brachial plexus nerve passed through the center of the tumor, which was intimately related to the brachial plexus nerve. Furthermore, the pressure caused the right brachial artery's trunk to shift downward, and the tumor received blood supply from the brachial artery's minor branches. The process was challenging.
In order to prevent injury to the brachial plexus nerve, the brachial artery branches surrounding the tumor were gently separated throughout the procedure.
The tumor was removed gradually with little bleeding, in line with the imaging examination's findings.
At ten, the tumor was entirely excised. After the procedure, the patient recovered nicely.
After cVRT treatment, the imaging of Case 2, a 59-year-old female patient, revealed that the tumor was encircled by the fifth and seventh cervical nerves and was intimately linked to the sixth cervical nerve. The tumor was clearly marked by the passage of the right subclavian artery. During the procedure, the subclavian artery and the fifth and seventh cervical nerves were carefully separated. The tumor was carefully exposed, cut slowly, and then carefully exfoliated to prevent injury to the sixth cervical nerve.
Following the procedure, the patient made a full recovery.
Following cVRT therapy, the tumor beneath the eighth cervical nerve on the right side of the 8-year-old female patient in Case 3 was visible. It had a close connection to the brachial plexus on the right. The right subclavian artery ran in front of the mass, and the eighth cervical nerve on the right was crushed and elevated. Following a 360-degree rotation, it was discovered that there was no doubt about the boundary between the eighth cervical nerve and the right subclavian artery. During the procedure, the tumor was entirely excised, and the right subclavian artery and right eighth cervical nerve were carefully separated.

After the procedure, the patient made a full recovery.
Preliminary findings have been obtained from visual study on the diagnosis of brachial plexus nerve injury in clinical practice. Corresponding research has also been carried out on the timing and method selection of brachial plexus nerve injury. We have also persistently experimented with clinical applications and discovered that cVRT vascular nerve fusion

technology may also detect lesions to a significant degree when tumor metastases penetrate the brachial plexus nerve and adjacent blood vessels.

Furthermore, it can also serve as a guide for the treatment of lesions surrounding the brachial plexus nerve that result from tumor compression.

SUMMARY

With the use of cVRT, which provided more precise and realistic picture data for clinical usage, the anatomical structure of the brachial plexus as well as the surrounding tumor lesions and blood arteries were displayed in three dimensions.

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