

Original Article

Clinical application of MPR nerve display technology in CT-guided desmoplastic fibroma cryotherapy

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Abstract: Objective: This study was designed to detect the application feasibility and accuracy of multiple planar reconstruction (MPR) nerve display technology in desmoplastic fibroma therapy via argon-helium cryoablation. Methods: 11 patients with systemic desmoplastic fibroma (8 males and 3 females) were recruited from XX hospital. Preoperative CT thin slice scan was performed on lesion area and MPR display technology was applied to detect the association between tumors and nerves, whose results determined surgery plans. The conformal distribution of cryoprobes and ablation range were determined based on real-time nerve display images during surgery. The curative effects were assessed instantly, 3 months, 6 months and 12 months after surgery via MPR display images and clinical symptoms. Results: All surgeries were completed successfully guided by MPR nerve display images. Nerve display images explicitly demonstrated the correlation of nerves with tumors before surgery, rapidly manifested whether probe distributions were accurate and whether ablation ranges were satisfactory during surgery, and completed reexaminations to observe the recovery conditions of neural structure and functions through imaging and clinical symptoms in different periods after surgery. After operations, all patients underwent good recoveries in neural functions, expressing gradual remission of symptoms (like pains and limb sensory disorders). Conclusion: In the treatment of desmoplastic fibroma through cryoablation, adopting MPR display technology can guarantee the protection for neural structure while maximally ablating tumors, and greatly improve the accuracy of surgery, thus avoiding complications. Therefore, this technology should be further applied in clinic.

Keywords: Cryoablation, image processing, computer-assisted, desmoplastic fibroma

Introduction

Desmoplastic fibroma is a rare tumor between benign and malignant, and surrounds adjacent vital structures (such as nerves and blood vessels) with invasive growth pattern. Clinically, it is treated using surgery as the preferred choice, but its recurrence rate is extremely high due to incomplete removal of tumors [1, 2]. So these tumors are treated with measures involving increasing image-guided minimally invasive techniques (like radiofrequency ablation, microwave ablation and cryoablation), especially argon-helium cryoablation which has been recognized as the most suitable method for soft tissue neoplasms with nerve injury as the most common complication [3, 4]. CT multiple planar reconstruction (MPR) nerve display technology, differing from conventional CT three-dimensional reconstruction or curve planar reconstruction, can display neuromechanism shape

factually and clearly, and visually distinguish the correlation of nerves with adjacent structures, so this technology has been applied in imaging diagnosis [5-8]. The purpose of using this technique in the process of argon-helium cryoablation for the first time in current study was to improve surgical effects, thus reducing operative complications and decreasing the recurrence rate of tumors.

Materials and methods

General information

11 patients diagnosed with systemic desmoplastic fibroma in XX hospital were enrolled in this study, including 8 males and 3 females aged from 14 to 71 with a median age of 34 years. Among them, 3 patients had tumors in the neck, 4 in pelvic cavity and 4 in chest and abdominal wall.

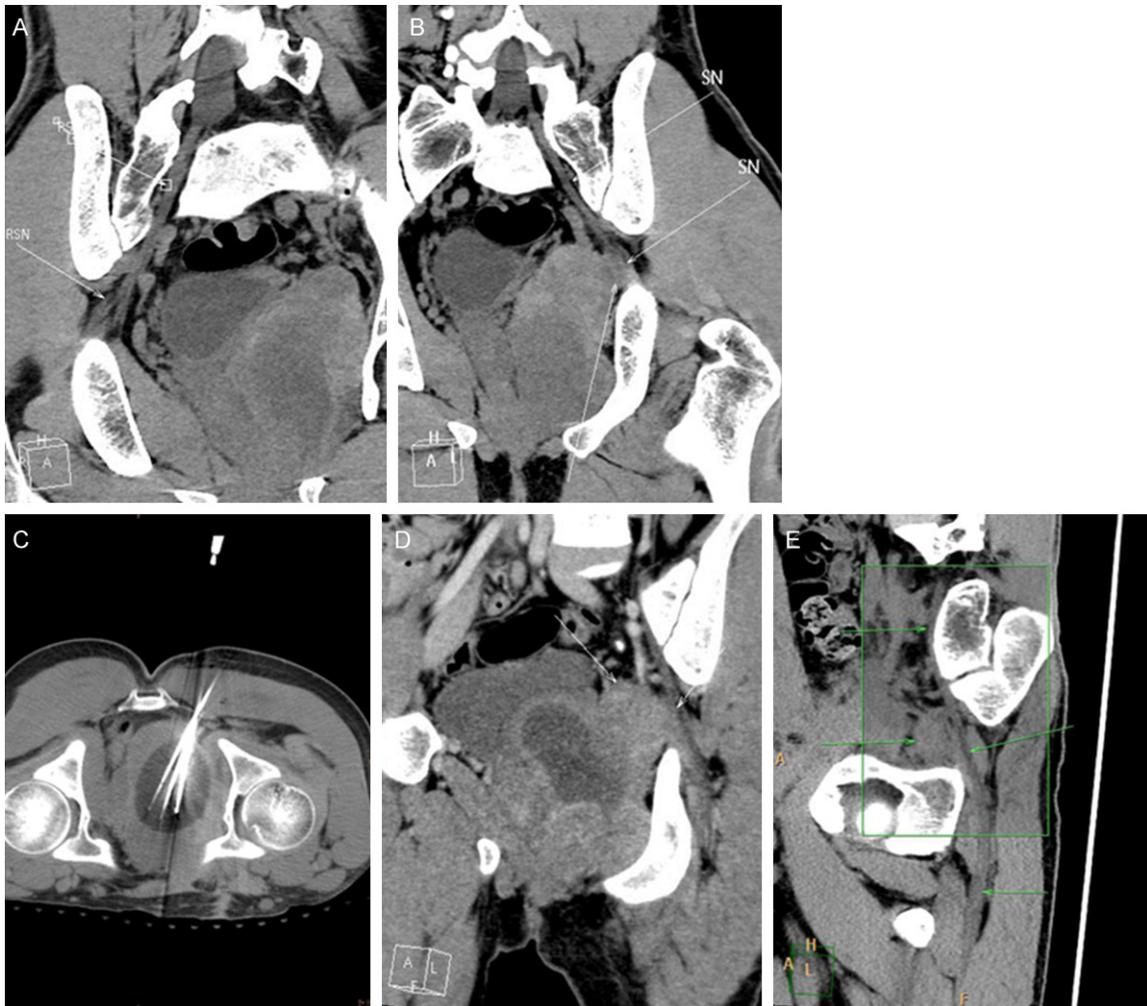


Figure 1. Preoperative MPR nerve images reveal the conditions of bilateral sciatic nerve (SN). In (A), the shape and thickness of right SN are normal (see arrows). (B) Shows that left SN in pelvis entrance is suppressed and violated by tumors without clear boundary (see arrows). Cryotherapy was performed based on preoperative nerve display images and MPR nerve display was implemented to observe the range of ice balls during surgery. In (C), Axial CT shows low density image of ice balls with clear boundary, while MPR nerve image in (D) displays the association of ablation range with adjacent SN (see arrows). (E) Was taken in patient's reexamination through MPR image 3 months after surgery, and it manifests that the volume of tumor is decreased and the distribution of left SN tends to be normal (see arrows).

Inclusion and exclusion criteria

Included patients must meet the following criteria: (1) with preoperative pathological diagnosis conforming to fibroma diagnosis and imaging diagnosis; (2) expressing obviously clinical symptoms; (3) without vital organs obstructing on the path of probe puncture planned by imaging; and (4) without remarkable abnormality in preoperative hematology and electrocardiogram (ECG) examinations. Patients were excluded if they fulfill any one of the following situations: (1) not able to tolerate ablation therapy because of poor health or their age; (2) expressing

abnormal hepatorenal function; and (3) with hematological index not satisfying surgical requirements [9, 10].

Equipment

The essential medical equipment included portable multi-parameter life sign monitor (Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China), homiothermic blanket (HI-CO-AQUATHERM660, HIRTZ, Germany), Cryo-Hit cryosurgery system (Israel), cryoprobe with an outside diameter of 1.47 mm, large bore 16 slice spiral CT (Philips Brilliance CT, Big Bore 16

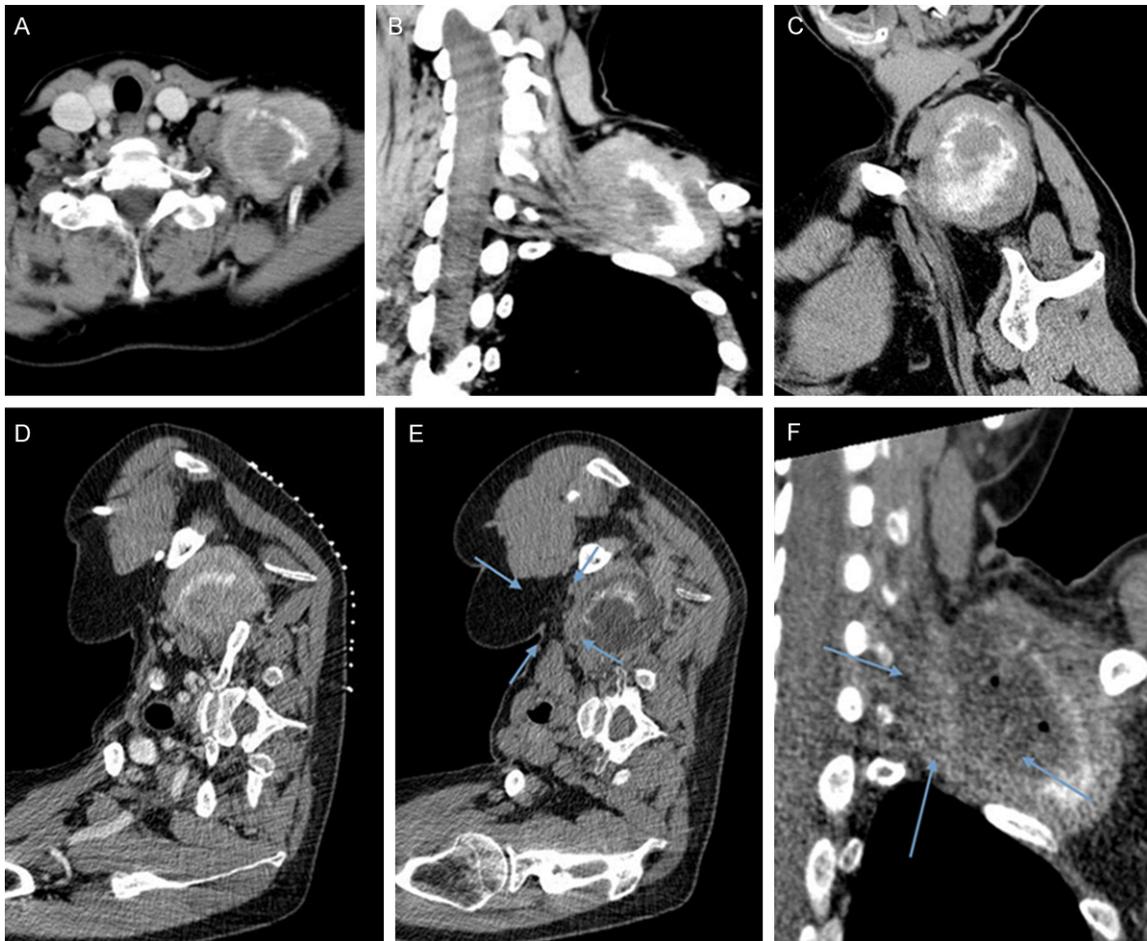


Figure 2. In (A), enhanced CT displays that tumor is located at left supraclavicular area and presses obviously on adjacent nerves and blood vessels (see arrows). MPR nerve images of (B and C) show obvious pressure and invasion on brachial plexus nerves at anterior inferior part of tumor (see arrows). Cryoablation was performed under right lateral decubitus according to preoperative reconstruction images, and axial CT in (D and E) reveal a low density of ice balls. Additionally, intraoperative MPR image of (F) demonstrates that the range of low-density ice ball has reached the border of neuromechanism.

CT) with a scan slice thickness of 0.6-5 mm using 120 kV tube voltage and 250 mAs tube current, and homemade paliform metal signs were used for location.

Methods

The general conditions of patients before operation were assessed through blood routine examinations, four coagulation tests, four indexes of serum, hepatorenal function and ECG examinations. Nerve MPR parameters were formulated based on lesion locations and the assessment of neural symptoms. Patients underwent enhanced examinations and nerve MPR before operation. Additionally, surgical postures were determined in preoperative plans according to the manifestation of tumor-nerve

relationship, and thus settled intraoperative MPR parameters (thickness and angle). Based on preoperative plans, CT-guided probes were arranged stepwise in tumors conforming to the situations with an interval of 1 cm. Freezing methods in different segments or gradations were applied to large lesions with a successive or separate pattern, and in principle, one cryoprobe would be added while the diameter of tumors increased 1.5 cm. Double circulation freezing-rewarming mode (freezing for 10-15 min and rewarming for 3-5 min) was adopted in all patients. Conventional scan and real-time nerve reconstruction images were used to monitor frozen scope during surgery and different time freezing method was applied to reduce the risk of cryodamage [11]. Postoperative CT scanning and nerve MPR images were per-

Table 1. CT results of 7 patients with desmoplastic fibroma at different time points after argon-helium ablations

Curative effects	3 months after surgery	6 months after surgery	9 months after surgery	12 months after surgery
CR	0	0	0	0
PR	7	8	8	8
SD	4	3	3	3
PD	0	0	0	0

Notes: CR, complete response; PR, partial response; SD, stable disease; PD, progressive disease.

formed immediately to observe whether frozen scope was satisfactory and whether adjacent nerves were violated. Patients took conventional hemostatics and antibiotics after returning to wards, and their urine was underwent alkalinized and hydration processes for monitoring biochemical indicators continuously [12, 13].

Therapeutic evaluation

(1) Imaging evaluation: For evaluating the curative effects, enhanced CT scan and nerve MPR images were applied instantly, 3 months, 6 months and 12 months after surgery respectively to compare tumor sizes, densities, changes in schedule of reinforcement, and recoveries of nerves and adjacent structures after surgery with those before surgery. (2) Clinical evaluation: Revised RECIST criteria were used to evaluate short-term effects. Changes in clinical symptoms of patients were evaluated at each time point, and the occurrence of postoperative complications were observed.

Results

Imaging manifestations

Guided by MPR nerve display technology, argon-helium conformal cryoablations were performed successfully in 11 patients. 3-8 cryoprobes were used once and 3 patients with larger lesions underwent 3-5 times cryoablations. The lesions were maximally ablated on the basis of same-slice imaging. The coverage rate of ice ball reached more than 90% in patients with smaller lesions. As for patients with larger lesions, first maximum ablation was performed targeting at the parts of tumors away from neuromechanism, and successive ablations were carried out after tumors lessened and the distribution of nerves became clear, so the final ablation range of ice balls could cover more than 80% of tumors. Enhanced

CT images and MPR nerve images performing at 3 months, 6 months, 9 months and 12 months after surgery showed obvious necrosis in ablation areas, decreased lesions and clear adjacent neuromechanism.

Therapeutic evaluation after surgery

Imaging therapeutic evaluations were completed according to imaging examination results in different periods, including enhanced CT and MPR nerve images (Figures 1 and 2). Table 1 displays the results.

Surgical complications and clinical symptom changes

2 pelvic tumor patients had different degrees of pains in buttocks and legs during surgical punctures and had distending pains at the beginning of freezing, and one of them had numb perineum and urination difficulty after surgery. One patient with abdominal wall tumor had strong puncture pain during surgery, and had skin frostbite after the third ablation. One patient with neck tumor had mild skin frostbite in the second ablation and got improved after symptomatic treatment. Pains subsided in all patients in postoperative reexaminations, and the pressure symptoms were markedly improved in patients with pelvic tumors.

Discussion

As a borderline tumor, desmoplastic fibroma can occur at any position in the body with a biological characteristic of invasive development. It frequently oppresses and violates adjacent neurovascular bundles to generate clinical symptoms. Previous surgical treatment would cause larger trauma, accompanied by high recurrence rate. In recent years, image-guided minimally invasive treatment techniques (such as cryoablation, radio frequency and microwave ablations) have been increasingly used in fibroma therapy. CT-guided argon-helium cryoablation therapy has become a preferred method in the ablations of soft tissue neoplasms, because during surgery, it can observe the shapes of ice balls clearly and control ablation range accurately and extensively. However, it has been the key for the curative effects of ablations to prevent adjacent neurovascular from damages while maximally ablating tumors [14, 15].

The significant structures around soft tissue fibrous tumors are mainly nerves and blood vessels. Wider blood vessels seldom undergo cryodamage due to their "thermal pool effect". While never is the critical factor affecting the curative effects of ablations because it is prone to frostbite and is not easily observed in conventional and reconstruction images. At present, unclear or incomplete display of neural structures in conventional imaging examination and reconstruction method cannot determine whether ablation range involves in nerves in cryoablation, thus resulting in incomplete ablation or nerve injury due to excessive ablation [16, 17]. Differing from traditional reconstruction methods, CT MPR display technology can obtain imaging results extremely approximating practically anatomical morphology, and thus distinctly reveal the relationship between nerves and tumors on the same image level. In this study, the advantages of CT MPR technology in minimal invasive therapy in tumors were as follows. First, fibrous tumors, usually with irregular shapes and large volume can be demonstrated their invasion of nervous more accurately and quickly in preoperative plans via this technology, so ablation probes could be distributed according to the correlation between tumors and nerves. Second, MPR images were adopted to observe the shapes of low density ice balls and the distances with adjacent nerves during operation so as to maximally ablate tumor issues while protecting neuromechanism. Third, in different periods after operation, this MPR technology, combined with enhanced CT images, was used to observe the necrosis and shrink of tumor issues and the recovery of neuromechanism so as to formulate subsequent therapeutic schedule timely.

Based on the characteristics of argon-helium cryosurgery, we improved various parameters of CT MPR display technology in this study to make it more efficient and precise in application, and make it more conducive to operational guide in surgery and to follow-up observation after surgery. The main improvements contained the following three aspects. Firstly, Fixed coordinates were defined according to lesion locations and adjacent structures (such as lesion-adjacent bony structures and vascular structures) before surgery, which contributed to intraoperative image reorganization and postoperative follow-up observation. Secondly, con-

ventional MPR nerve display technique had to scan patients with a standard position for obtaining better displays of nerve distribution so as to find lesions. However, clear display of neuromechanism around lesions was enough for freezing fibroma. Therefore, the patients' positions were determined in accordance with lesion positions and surgery plans before surgery, and the neuromechanism and lesions were demonstrated through individualized image reconstruction. Thirdly, during postoperative follow-up, the comparison of neural structures between diseased side and healthy side through nerve reconstruction display scanned under standard position was conducive to estimate the recovery situation of nerves.

Based on preoperative plans, ablations guided by MPR nerve display technology were successfully performed on 11 patients, showing satisfactory control over lesions and no injury on neurological functions. Ice ball coverage rate of single ablation reached more than 90% in smaller lesions. While the ice ball coverage rate of accumulated ablations achieved more than 80% in larger lesions which were ablated by several times because their structures were complex and patients could not bear prolonged surgery. Real time MPR nerve display was performed during surgery according to the formation range of ice balls. When the range of low density ice balls was displayed to be near nerves, freezing would be timely terminated based on patients' situation to protect the functions of adjacent nerves. When it came to nerve-invading lesions without clear boundary, if MPR technology could not distinguish the association between tumors and nerves, lesions away from neuromechanism were ablated first, and those closed to neuromechanism were ablated after the necrosis and shrink of partial tumors, so that irretrievable damage in nerves would not be generated due to excessive range of single ablation.

In conclusion, CT MPR images can accurately and reliably show neuromechanism, direct ligation therapy via, improve the accuracy of surgery on desmoplastic fibroma through guiding argon-helium cryoablation, thus maximally reducing tumor burden, clinical symptoms and tumor recurrence rate. Therefore, this technology should be further popularized and applied in clinic.

Disclosure of conflict of interest

None.

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References

- [1] Skapek SX, Ferguson WS, Granowetter L, Devadas M, Perez-Atayde AR, Dehner LP, Hoffer FA, Speights R, Gebhardt MC, Dahl GV and Grier HE. Vinblastine and methotrexate for desmoid fibromatosis in children: results of a Pediatric Oncology Group Phase II Trial. *J Clin Oncol* 2007; 25: 501-506.
- [2] Stoeckle E, Coindre JM, Longy M, Binh MB, Kantor G, Kind M, de Lara CT, Avril A, Bonichon F and Bui BN. A critical analysis of treatment strategies in desmoid tumours: a review of a series of 106 cases. *Eur J Surg Oncol* 2009; 35: 129-134.
- [3] Havez M, Lippa N, Al-Ammari S, Kind M, Stoeckle E, Italiano A, Gangi A, Hauger O and Cornelis F. Percutaneous image-guided cryoablation in inoperable extra-abdominal desmoid tumors: a study of tolerability and efficacy. *Cardiovasc Intervent Radiol* 2014; 37: 1500-1506.
- [4] Wang Y, Wang W and Tang J. Ultrasound-guided high intensity focused ultrasound treatment for extra-abdominal desmoid tumours: preliminary results. *Int J Hyperthermia* 2011; 27: 648-653.
- [5] Ye Q, Huang W, He Y, Nong M, Liang T, Tan S and Yang X. [Application of posterior spinal canal reconstruction in surgery of intraspinal tumor]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 2014; 28: 965-968.
- [6] El-Gammal TA, Saleh WR, El-Sayed A, Kotb MM, Imam HM and Fathi NA. Tendon transfer around the shoulder in obstetric brachial plexus paralysis: clinical and computed tomographic study. *J Pediatr Orthop* 2006; 26: 641-646.
- [7] Bai RJ, Li N and Zhang JX. Diagnostic value of 64 slice CT myelography MPR in the damage of cervical nerve root. *Chinese Journal of Radiology* 2007; 41:6569-573: 647-651.
- [8] Lin JF, Li YY and Wang ZY. Anatomy characteristics and clinical value of CT MPR display in lumbar nerve root. *Chinese Journal of Radiology* 2007; 41:6645-649: 652-658.
- [9] Cornelis F, Italiano A, Al-Ammari S, Kind M, Stoeckle E, Gangi A, Palussiere J and Bui BN. Successful iterative percutaneous cryoablation of multiple extraabdominal desmoid tumors in a patient with Gardner syndrome. *J Vasc Interv Radiol* 2012; 23: 1101-1103.
- [10] Nye H. Technology. Hospital pushes digital envelope, lets patients control records. *Hosp Health Netw* 2009; 83: 10-11.
- [11] Zhang X, Tian J, Zhao L, Wu B, Kacher DS, Ma X, Liu S, Ren C and Xiao YY. CT-guided conformal cryoablation for peripheral NSCLC: initial experience. *Eur J Radiol* 2012; 81: 3354-3362.
- [12] Foster RC and Stavas JM. Bone and soft tissue ablation. *Semin Intervent Radiol* 2014; 31: 167-179.
- [13] Filippiadis DK, Tutton S, Mazioti A and Kelekis A. Percutaneous image-guided ablation of bone and soft tissue tumours: a review of available techniques and protective measures. *Insights Imaging* 2014; 5: 339-346.
- [14] Lippa N, Sargos P, Italiano A, Kind M, Dallaudiere B, Hauger O and Cornelis F. Standardization of selection criteria for percutaneous image-guided cryoablation of recurrent soft-tissue sarcomas. *Diagn Interv Imaging* 2014; 95: 1071-1077.
- [15] Cornelis F, Havez M, Lippa N, Al-Ammari S, Verdier D, Carteret T, Amoretti N, Gangi A, Palussiere J, Hauger O and Grenier N. Radiologically guided percutaneous cryotherapy for soft tissue tumours: A promising treatment. *Diagn Interv Imaging* 2013; 94: 364-370.
- [16] Callstrom MR and Kurup AN. Percutaneous ablation for bone and soft tissue metastases-why cryoablation? *Skeletal Radiol* 2009; 38: 835-839.
- [17] Sabharwal T, Katsanos K, Buy X and Gangi A. Image-guided ablation therapy of bone tumors. *Semin Ultrasound CT MR* 2009; 30: 78-90.