Iran Red Crescent Med J. 2022 May; 24(5):e1511 doi: 10.32592/ircmj.2022.24.5.1511

Published online 2022 May 20

Case Report

Precise Soft-Tissue Sarcoma Operation Based on Three-Dimensional Modeling Technology: A Case Study

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Received 2021 September 17; **Revised** 2021 November 19; **Accepted** 2022 May 02.

Abstract

Background: Soft-tissue sarcomas are cancerous growths of mesenchymal tissues, most commonly arising from fat, muscles, and other connective tissues. Due to the fact that these tumors often lie adjacent to nerves and blood vessels, it is difficult to remove them. Traditional surgery is often carried out according to the operator's discretion and experience of local anatomy; however, the surgery bears the risk of damage to nerves and blood vessels. In cases of postoperative recurrence, the local anatomy is often not clear due to scar formation, and the risk of operation would be greater.
Case presentation: This report describes the application of three-dimensional (3D) modeling prior to surgery, which can clearly reveal the tumor tissue and the surrounding important nerves and blood vessels.
Conclusion: In two operations for recurrent soft-tissue sarcoma of the thigh with complex adjacencies, it was found that 3D models are of great value for preoperative planning and intraoperative navigation. More importantly, these models can improve the success rate of surgery and reduce the operative time.

Keywords: Precise operation; Recurrence; Soft-tissue sarcomas, Three-dimensional Modeling technology

1. Background

The three-dimensional (3D) model can clearly show the shape of the tumor and its spatial relationship with the adjacent blood vessels and nerves and simulate surgery *in vitro* (1-4). The application of printing technology in the multidisciplinary cooperation mode to assist complex tumor surgery demonstrates the overall view of the multidisciplinary cooperation mode and the advantages and safety of personalized operation schemes (5). Moreover, it can play the role of 3D modeling technology in accurate and complete resection of tumors, effectively shortening the operation time and reducing blood loss (1, 6), and improving the safety of tumor resection.

Combined with 3D modeling technology, reconstruction of tumors and surrounding important tissue models can help surgeons clearly and intuitively grasp the anatomical morphology of tumors and the surrounding tissue (3,6,7). In addition, it can lead to accurate and complete resection of the tumor tissue. There are many cases of 3D modeling technology in the medical field at home and abroad, mainly used in orthopedic material preparation, thoracic surgery, maxillofacial plastic surgery, hepatobiliary surgery, and other disciplines (2,6, 8-11). However, there are few reports on the application of this technology in the surgical treatment of complex soft tissue malignant tumors (12). This paper reports the complete resection of a complex soft tissue malignant tumor of the left thigh under the guidance of 3D modeling technology.

2. Case presentation

Case 1: A 69 -year-old woman presented with a chief complaint of a left thigh tumor that was resected 22 years ago and had recurred for the past 7 years. The patient was diagnosed with Liposarcoma of the left thigh (Figures 1, 2, 4).

Case 2: A 43 -year-old man presented with a chief complaint of a left thigh tumor that was resected 20 years ago and had recurred for the past 10 years. The patient was diagnosed with myxofibrosarcoma of the left thigh (Figures 1, 3, 4).

2.1. Data acquisition, 3D reconstruction, and 3DP

Patient-specific 3D reconstruction and 3DP models were completed. The two patients underwent enhanced computed tomography (Revolution CT, GE Healthcare, Milwaukee, USA) with a slice thickness of 0.625 mm. Afterward, the acquired CT data, in DICOM format, were imported into Mimics 23.0 and 3-matic 15.0 software (Materialise NV, Leuven, Belgium), and segmentation, editing, registration, and other rapid 3D reconstruction processes were implemented to reconstruct 3D digital models. After processing, the 3D reconstruction models were transformed into the stereolithography format for 3DP, and finally, a physical model of the STS was fabricated (Figure 5).

2.2. Operation

Case 1: The operation was performed in the prone position according to the preoperative incision design. The tumor was deep to the ischian nodule,

Figure 1. Case 1(A, B): The tumor was located on the posterior thigh.The left thigh was covered with surgical scars of approximately 20 cm. Case 2 (C, D): The tumor was located in the anteromedial aspect of the femur. The left thigh was covered with surgical scars of approximately 15 cm

and the distal portion continued to the knee joint. Intraoperatively, the sciatic nerve was found to be encapsulated by a mass, which was compatible with that in the 3D image. Due to the preoperative planning, the sciatic nerve was first found at the proximal end of the tumor intraoperatively and then carefully isolated and protected in the tumor tissue. Therefore, the injury of the sciatic nerve was avoided during the operation. The left lower extremity was normal in feeling and movement after the operation (Figure 6).

Case 2: The operation was performed in the supine position according to the preoperative incision design. Preoperative observation 3D imaging showed that the tumor was closely related to the femoral nerve and femoral artery. Therefore, the femoral nerve was first explored and revealed intraoperatively, and it was protected. The femoral artery was then explored at the groin and gradually separated distally, and the femoral artery could be seen traversing the tumor. Moreover, the vascular forceps were blunt separated and fully revealed the main femoral artery trunk and the lateral femoral circumflex artery. The vascular wall of the femoral

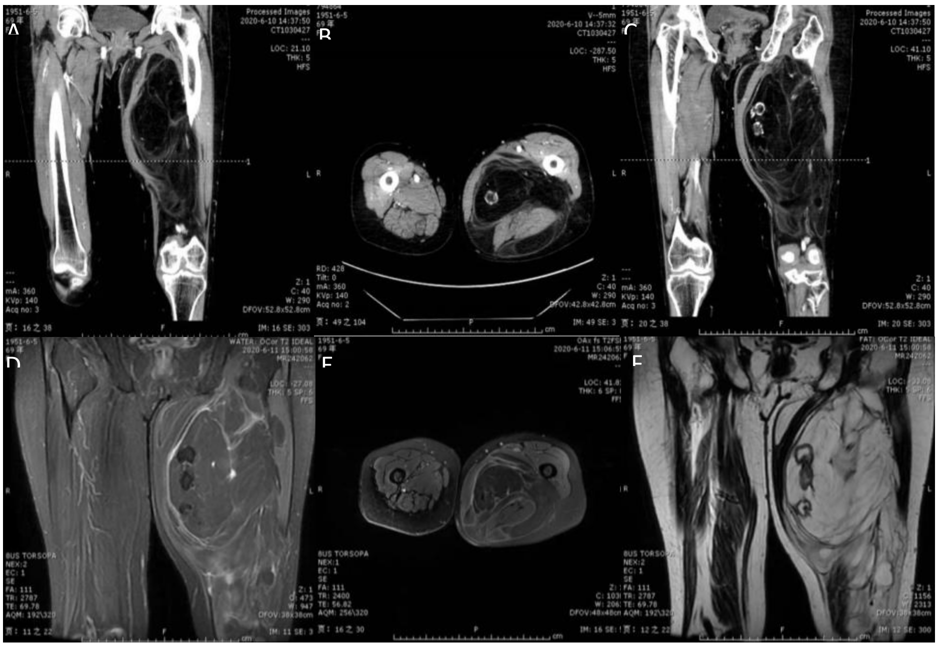

Figure 2. Computed tomography images of case 1A-C: In the left thigh, there was a large fat density mass in the medial and posterior femoral muscle space with irregular shape and unclear boundary. There was strip-like soft tissue density in the mass (dimensions: 29.1 cm×16.1 cm×7.2 cm). Magnetic resonance imaging of case 1D-F: There was a large fat signal mass in the medial posterior femoral muscle space of the left thigh with irregular shape and unclear boundary. There was strip-like soft tissue signals within it (dimensions: 27.8 cm×16.1 cm×6.2 cm)

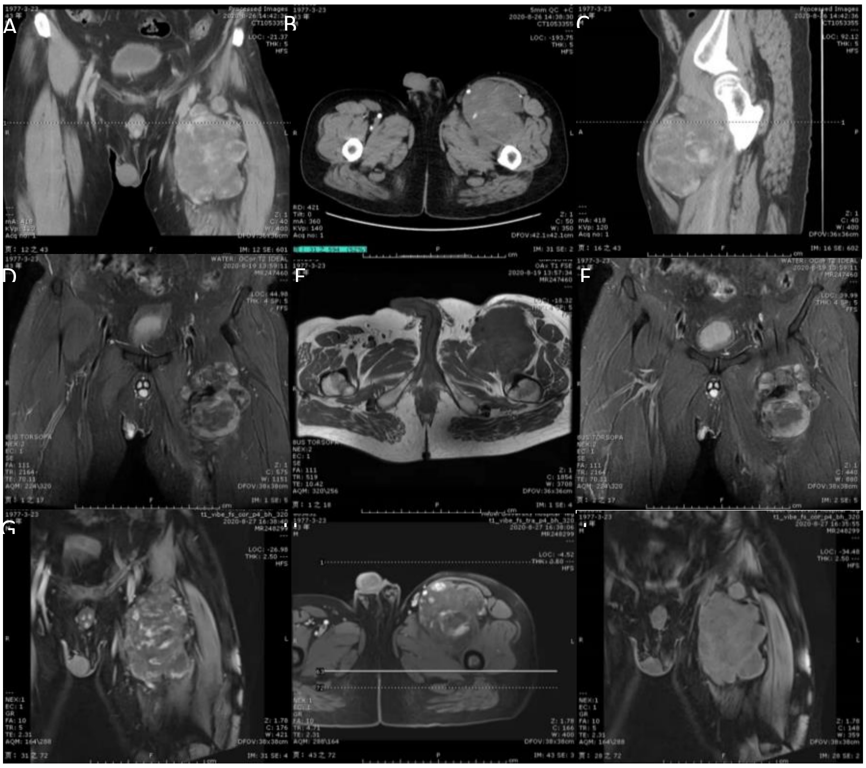

Figure 3. Computed tomography images of case 2A-C: In the soft tissue of the left front thigh, there were massive mixed density shadows with unclear boundaries (dimensions: 10.7cm×8.9cm×13.1cm). The enhancement scan showed obvious heterogeneous enhancement, showing delayed enhancement, and no obvious abnormality in adjacent bone. Magnetic resonance imaging of case 2D-F: In the left femur soft tissue, there were irregular, slightly long and equal T1 and equal and long T2 signal masses, which fused into clusters. The maximum coronal plane was 9.3 cm×10.2 cm. Enhanced magnetic resonance imaging (G-I): An irregular mass with heterogeneous enhancement was found in the soft tissue of the left thigh (dimensions: 10.2 cm×9.0 cm×14.1 cm). Blood vessels can be seen in it, and the adjacent structures are compressed and displaced

profound artery was hard and adherent to the tumor so severely that it was difficult to separate. Therefore, we ligated the femoral profound artery and avoided damaging it leading to major bleeding. The sensation and blood supply of the left lower limb were normal postoperatively (Figure 6).

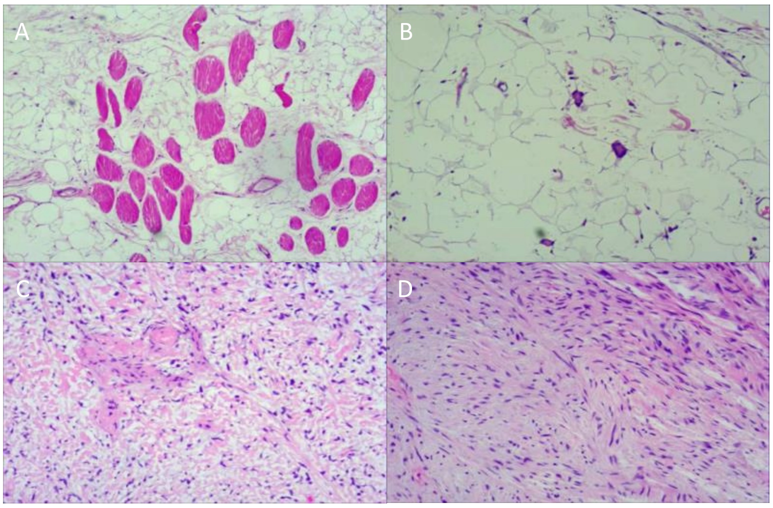

Figure 4 A, B: Histological findings from the biopsy specimen of Case 1. Under the microscope, adipose derived tumors were seen, most of the cells were well differentiated, striated muscle fibers could be seen, fat necrosis and calcification could be seen in some areas, and lipoblasts could be seen in a few areas. Considering intramuscular lipoma, some areas were atypical lipomatous tumor/well-differentiated liposarcoma. C, D: Histological findings from the biopsy specimen of Case 2. A spindle cell tumor with myxomatosis in front of the left thigh was considered a low-toxicity malignant myxofibrosarcoma

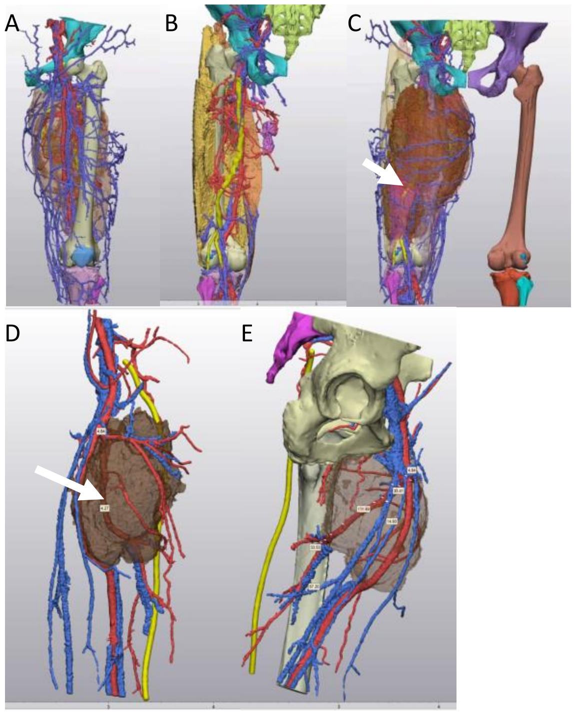

Figure 5. A-C (Case 1): Tumor tissue was seen on the medial posterior aspect of the femur. Tumor spread ranged from the lesser trochanter proximally to the knee joint distally. Multiple nerves and blood vessels were found around the periphery, and the tumor tissue completely enveloped the sciatic nerve (arrow in Figure C.) D-E (Case 2): The tumor tissue was located in the anteromedial aspect of the femur, surrounding a large number of arterioveins, and they were closely connected, including the femoral artery, femoral vein, and their branches. The deep femoral artery crossed over the tumor tissue (arrow in Figure D)

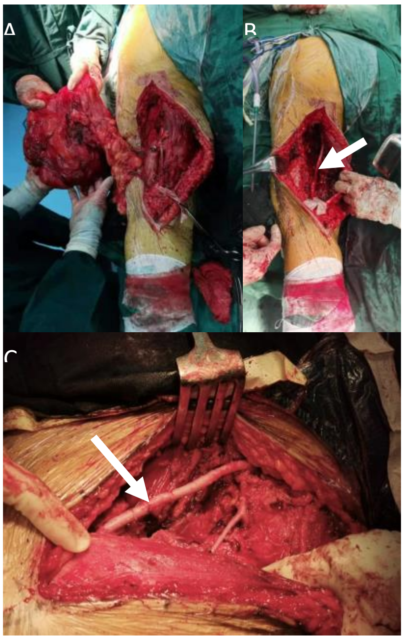

Figure 6 Case 1A, B: Resected tumor histomorphology (A); arrows point to the Sciatic nerve (B). Case 2C: Arrows point to the femoral artery

3. Discussion

Soft-tissue sarcomas occur throughout the body, but 40-60% of soft-tissue sarcomas are found in the lower extremities with the majority of these in the thigh (13). Malignant tumors of the soft tissue of the thigh are common primary tumors in orthopedics. Since it is often adjacent to nerves and blood vessels, removal of the tumor is difficult.

Traditional surgery usually takes place according to the knowledge of the local anatomy and the experience of the surgeon. However, most of the tissue structure will change with the growth of tumor tissue, especially when the tumor grows larger. The normal nerves and blood vessels change their normal anatomic position due to the compression of tumor tissue. In case 1, the sciatic nerve was completely penetrated by the tumor tissue. If there was no accurate location of the sciatic nerve with 3D modeling before the operation, it would have been very easy to damage the sciatic nerve during the operation, resulting in serious consequences.

The above-mentioned two cases were patients with postoperative recurrence with heavy local soft tissue adhesion and unclear anatomical levels. Preoperative examination showed that the tumor tissue was closely related to nerve and blood vessels, the adhesion was considerable, and the nerves and blood vessels could be easily damaged during the operation. In case 2, femoral artery and tumor adhesion was observed, and the femoral artery wall was more brittle than normal. Although we were very careful in the separation process, there was still femoral artery rupture and bleeding, which was repaired during the operation. Since this was an expected problem before the operation, we did not cause more serious consequences.

The application of the 3D modeling model in preoperative simulation can improve the operation accuracy, predict the operation risk, shorten the operative time, reduce intraoperative blood loss, and promote the rehabilitation of patients (2). However, preoperative modeling and intraoperative guidance for soft tissue malignant tumor surgery are rarely used.

At present, the examination of soft tissue tumors mainly includes B-ultrasound, magnetic resonance imaging, and CT. Although these examinations can show the location of the tumor well, they are still only planar images, and the overall shape and adjacent relationship of the tumor are not displayed enough. The 3D modeling of the tumor can show the anatomical structure more intuitively and can present the soft tissue and peripherally important nerves and vessels at the same time (3,4). It is convenient for the whole treatment team to observe and discuss the operative plan. In addition, for patients without medical knowledge backgrounds, it is easier to carry out preoperative communication and presentation of surgical plans.

Since the above two malignant thigh tumors were closely connected with the sciatic nerve, femoral artery, and femoral vein, the operation was difficult. Prior to operation, 3D modeling technology was used to reconstruct the tumor and the surrounding important tissue models. The operation was carried out according to the preoperative plan, and the nerves and blood vessels were exposed and protected strictly according to the plan.

We were able to avoid the injury to important nerves and blood vessels during the operation and also reduce intraoperative bleeding and unnecessary blood transfusion. Moreover, we revealed the tumor boundary more clearly according to preoperative planning to achieve complete tumor resection and reduce recurrence. This has important guiding significance for precision surgery, which can improve the success rate of surgery and reduce the operative time (14, 15).

The 3D printing has been used for several purposes to help surgeons better understand anatomy, sharpen their skills, and guide the identification of lesions and their relationship with the surrounding structures. It can be used for surgical planning, education, and patient counseling to improve the decision-making process (16).

In 2018, the Radiological Society of North America Special Interest Group on 3D Printing published guidelines on the clinical scenarios in which 3D printing may serve the greatest usefulness based on a comprehensive review of the literature. Among the most appropriate stated uses were preoperative planning for complex bone and connective tissue neoplasms well integrated into adjacent neurovascular structures (17).

The 3D printing has been most widely used for resident and medical student training across various cranial and spinal applications, as well as for an explanation of complex anatomy and surgical plans to patients in the preoperative setting (18).

Within spinal surgery specifically, previous works have reported successful clinical implementation of patient-specific 3D-printed implants used in challenging spinal stabilization and reconstruction cases (19-21).

In complex soft tissue tumor surgery, especially for recurrent malignant soft tissue tumors, we suggest the use of 3D modeling techniques. It can help surgeons clearly and intuitively grasp the anatomical morphology of tumors and the surrounding tissues. In the future, a workstation can be established in the operating room for the display of 3D digital models and life-size 3DP models to facilitate intraoperative navigation.

The use of 3D modeling technology in the orthopedic application has resulted in shortened operative time and has improved the success rate of surgery and less intra-operative blood loss.

4. Conclusion

In two operations for recurrent soft-tissue sarcoma of the thigh with complex adjacencies, it was found that 3D models are of great value for preoperative planning and intraoperative navigation. More importantly, these models can improve the success rate of surgery and reduce the operative time.

Acknowledgments

First and foremost, the authors would like to show my deepest gratitude to the 3D Printing Center of the Affiliated Hospital of Hebei University. The authors would also like to thank all of their friends, especially Jing Wang and Pan Wang, for their help and support.

Footnotes

Conflicts of Interest: None to declare.

Authors' contributions: Xiao-Zhe Zhou: Data analysis, drafting the article; Bao Ren, Xiong Zhang, Ji-Long An: Data collection; Ke Zhang: 3D reconstruction; Wen-Shan Gao: Revision and final approval of the manuscript.

Funding/Support: This study was funded by the Key Research and Development Program of Heibei Province (grant number 20190934).

Ethical considerations: For this type of study, institutional review board approval was not required.

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