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Feeding arteries and arteriovenous shunt for discrimination of soft tissue tumors

Gang Wu, PhD[a], Hao Yang, MD[b,*], Xiaoming Li, PhD[a,*]

Abstract

Time resolved magnetic resonance angiography with interleaved stochastic trajectories (TWIST) allows for identification of tumor feeding arteries and arteriovenous shunt (AVS). We used TWIST to obtain number of feeding arteries (NFA) and detect AVS for 43 cases of pathology-confirmed soft tissue tumors. We compared normalized number of feeding arteries (nNFA) and AVS between malignant and benign tumors, and found nNFA was significantly greater in malignant tumors versus benign tumors (2.1 vs 1.3, $P < .05$). The incidence of AVS was significantly higher in malignant tumors versus benign tumors (87.5% vs 10.5%, $P < .05$). TWIST derived nNFA and AVS could be useful in the discrimination of benign and malignant soft tissue tumors.

Abbreviations: AVS = arteriovenous shunt, MIP = maximum intensity projection, NFA = number of feeding arteries, nNFA = normalized number of feeding arteries, TWIST = time resolved magnetic resonance angiography with interleaved stochastic trajectories.

Keywords: arteriovenous shunt, feeding artery, lower extremity, magnetic resonance angiography, soft tissue tumor

1. Introduction

Tumor feeding arteries and arteriovenous shunt (AVS) are important imaging signs in evaluating soft tissue tumors,[1] and both could be well displayed with DSA. However, DSA is invasive and expensive, and exposes patients to ionizing radiation.[2,3] Time resolved magnetic resonance angiography (MRA) is thus developed to serve as a non-invasive alternative to DSA. Time resolved magnetic resonance angiography with interleaved stochastic trajectories (TWIST) is reported to provide adequate temporal and spatial resolution for generating arterial images without venous pollution,[4–6] so is feasible for identification of feeding arteries and AVS.

Some MRI techniques have been tried to discriminate benign from malignant soft tissue tumors.[7–10] However, there are few publications investigating the feasibility of TWIST derived number of feeding arteries (NFA) and AVS in discrimination of soft tissue tumors. We hypothesized here TWIST is reliable in identifying tumor feeding arteries and AVS. The purpose of the study is, therefore, to determine whether NFA and AVS are helpful in discriminating benign from malignant soft tissue tumor.

2. Methods

This retrospective study was approved by the Institutional Review Broad of university. Inclusion criteria were as follows:

1. patients with soft tissue tumors in lower extremities;
2. patients underwent time resolved MRA for evaluating vascular invasion by tumor;
3. TWIST was performed before operation or biopsy;
4. pathology result for tumor was available;
5. tumor is definitely benign or malignant according to WHO classification.

The 43 patients (male = 23, female = 20, age range = 24~72 years, mean age = 42.7 years) with pathology-confirmed soft tissue tumors in lower extremities and pre-operation vascular evaluation with TWIST during January 2015 and August 2017 were respectively analyzed. The main symptoms or signs were as follows: soft tissue mass (n = 38); leg pain (n = 25); leg edema (n = 11). All patients underwent TWIST examinations before operation or biopsy for tumor. All MR examinations were performed on a 3.0T whole-body MR scanner (Magnetom Skyra, Siemens Healthcare, Enlargen, Germany). TWIST was performed in the coronal plane with the following parameters: TR/TE, 2.8/1.01 ms; flip angle, 25°; Field of View, 450 mm × 360 mm; slice thickness, 1 mm; slice number, 72 or more; matrix, 448 × 358.4; A&B, 15%/20%; GRAPPA factor, 2; number of measurements, 25. Temporal resolution was 3.8 seconds. Gadobutrol was injected at a rate of 2.5 ml/s during the first frame of TWIST. The total acquisition time for TWIST with 25 frames and 72 slices per frame is 118 seconds.

The 43 cases of soft tissue tumors were divided into 2 groups according to WHO classification of tumors of soft tissue and bone:[11] benign group and malignant group. There were 24 malignant cases and 19 benign cases.

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Table 1

Pathological results.

Malignant (n = 24)		Benign (n = 19)	
Myxofibrosarcoma	n = 2	hemangioma	n = 9
Fibrosarcoma	n = 7	schwannoglioma	n = 2
Alveolar soft part sarcoma	n = 3	liomyoma	n = 2
Epitheliosarcoma	n = 1	fibroma	n = 3
Liposarcoma	n = 5	neurofibroma	n = 3
Rhabdomyosarcoma	n = 2		
Synovial sarcoma	n = 2		
Leiomyosarcoma	n = 2		

Maximum intensity projection (MIP) of subtracted TWIST images was used to identify feeding arteries and AVS. MIPs were viewed consecutively, similar to DSA, for the evidence of AVS. Two radiologists with 11 and 13 years' experience blinded to pathology results in consensus determined NFA for each tumor. They also determined in consensus whether or not tumors had AVS. A radiologist with 10 years' experience blinded to pathology results measured tumor volume for all cases in random order. The normalized number of feeding arteries (nNFA) was calculated according to the following formula: $nNFA = (NFA/volume) \times 100\,cm^3$.

2.1. Statistical methods

A Mann–Whitney test was used to compare nNFA between the 2 groups, as well as tumor volume. The non-paired student's *t* test was used to compare age. A chi square test was used to compare AVS incidence between the 2 groups, as well as gender. All data analysis was performed with SPSS (version 21.0, IBM, USA). *P* values less than .05 were considered statistically significant differences.

Table 2

Comparisons between benign and malignant soft tissue tumor.

	Malignant (n = 24)	Benign (n = 19)	*P*
Mean age (yr)	45.2	39.5	.14
Male: female	13:11	10:9	.63
Tumor volume	134.8 ± 37.4	79.5 ± 22.1	<.001
Mean nNFA	2.1	1.3	.009
Incidence of AVS	87.5% (21/24)	10.5% (2/19)	<.001

AVS = arteriovenous shunt, nNFA = normalized number of feeding arteries.

3. Results

There was no significant difference in age or gender ($P > .05$) between benign group (n = 19, mean age = 39.5 years, male: female = 10:9) and malignant group (n = 24, mean age = 45.2 years, male:female = 13:11).

The mean volume of malignant tumors was $134.8 \pm 37.4\,cm^3$. The mean nNFA for malignant tumors was 2.1. Minimum and maximum of nNFA of malignant cases was 1.6 and 4.4, respectively. AVS was identified in 21 out of 24 (87.5%) malignant tumors.

The mean volume of benign tumors was $79.5 \pm 22.1\,cm^3$. Feeding artery was not identified in 4 benign cases. Only 1 feeding artery was identified in 11 benign cases. For the other 4 benign cases, 2 feeding arteries were identified. The mean nNFA for benign tumors was 1.3. Minimum and maximum of nNFA of benign cases was 0 and 2.6, respectively. AVS was identified in 2 out of 19 (10.5%) benign tumors.

Table 1 shows the pathology results for all cases. Table 2 shows the comparisons between benign and malignant tumor. Tumor volume was significantly greater in malignant group versus benign group ($P < .001$, see Table 2). Malignant tumors had significantly more feeding arteries than benign tumors ($P < .05$, see Table 2). The AVS incidence was significantly higher in malignant tumors than in benign tumors ($P < .001$, see Table 2). Figures 1, 2 and 3 are

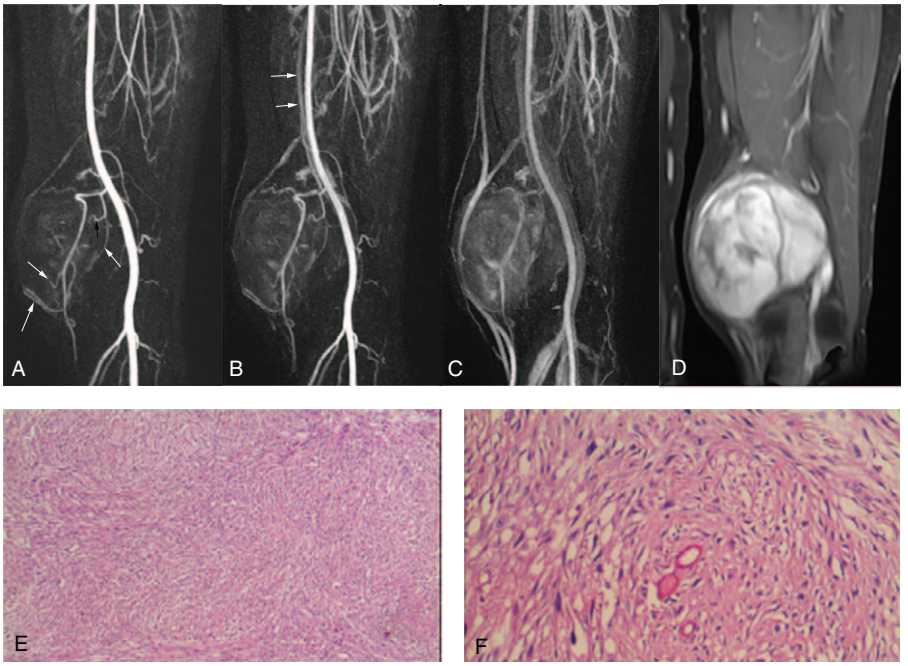

Figure 1. Multiple feeding arteries were identified in the arterial image (A, arrows). AVS was clearly displayed at later time points (B, C, arrows). T1 enhanced image did not display any feeding artery or AVS (D). The pathological result was fibrosarcoma (E, F). AVS = arteriovenous shunt.

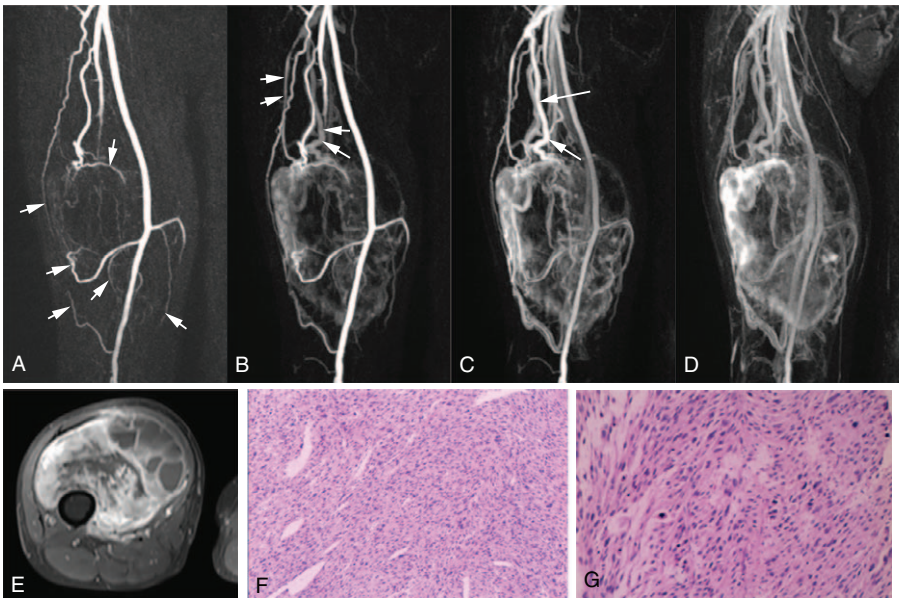

Figure 2. Lots of feeding arteries were clearly displayed at the arterial image (A, arrows). At a later time points, small veins appearing ahead of time (B, C, arrows) indicated AVS. Tumor draining veins were clearly displayed at C and D. Contrast enhanced T1 image (E) did not show feeding arteries or AVS. It was an alveolar soft part sarcoma (F, G). AVS = arteriovenous shunt.

examples of malignant tumors with AVS and multiple feeding arteries. Figure 4 is an example of benign tumor without AVS.

4. Discussion

The current study found benign and malignant soft tissue tumor differed in feeding artery numbers and AVS incidence. We also found TWIST provided excellent arterial images for all cases.

The spatial resolution of TWIST is sub-millimeter. That is why TWIST could well display feeding arteries of small size. The time resolution of TWIST is less than 4 seconds. Multiple arterial frames could be obtained with this method. Thus AVS could be reliably detected.

In fact, we found some feeding arteries were absent at early time points of TWIST, but appeared at later time points. That is why some feeding arteries were missed with conventional single-point MRA or computed tomography angiography (CTA). Time

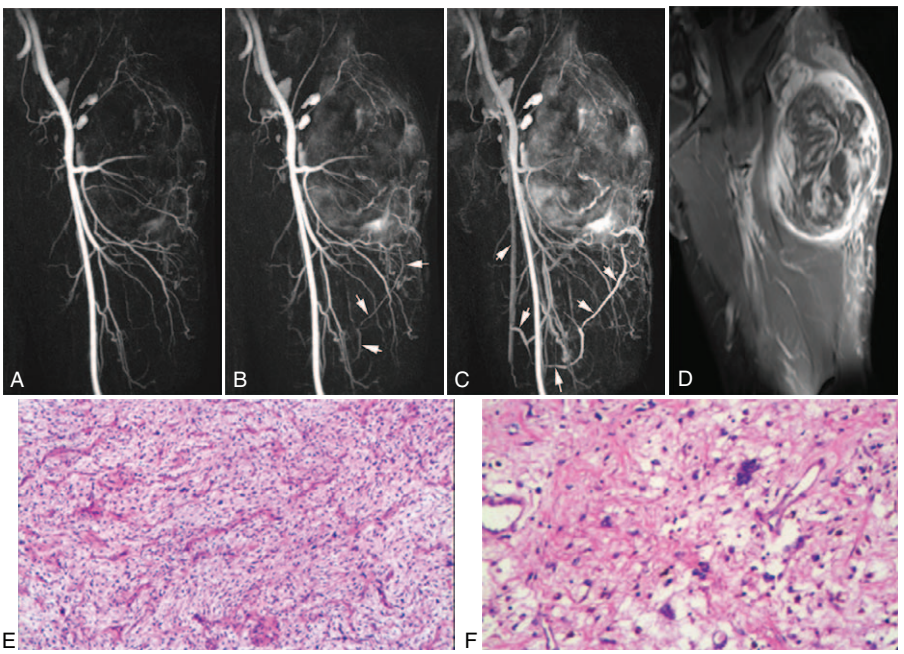

Figure 3. Lots of feeding arteries were displayed in the arterial image (A). A draining vein appeared at a later time point (B, arrows). The whole path of the draining vein was better shown at C. Contrast enhanced T1 image failed to show feeding arteries or AVS (D). Pathological result was myxofibrosarcoma (E, F).

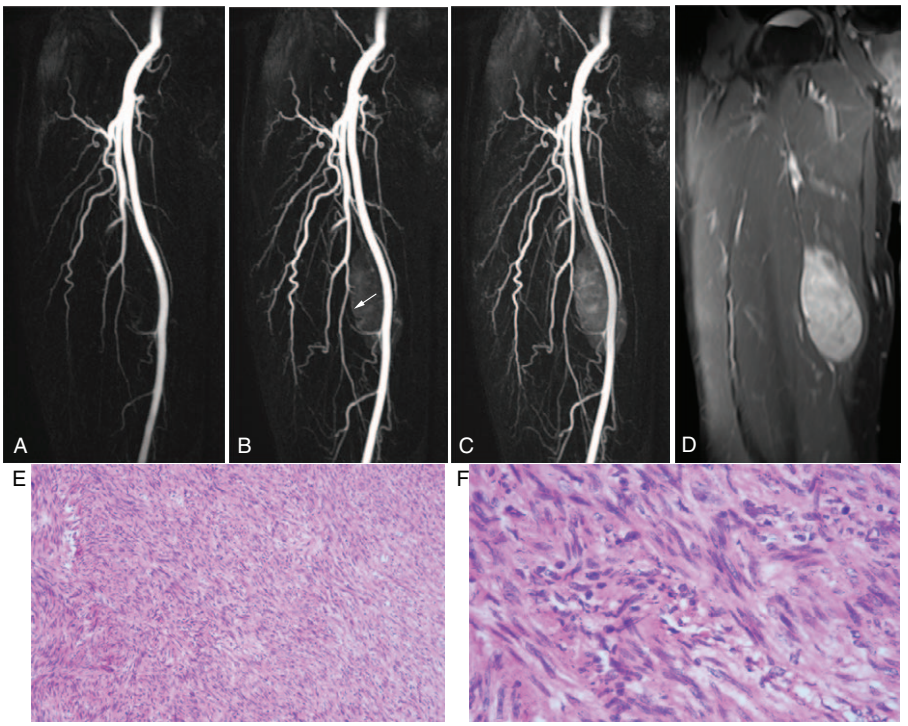

Figure 4. TWIST identified a feeding artery for this tumor (A, B, C, arrow). No AVS was identified with TWIST or T1 enhanced image (D). Pathological result was liomyoma (E, F). AVS = arteriovenous shunt, TWIST = time resolved magnetic resonance angiography with interleaved stochastic trajectories.

resolved MRA obtaining images at multiple time points seemed superior in identification of feeding arteries.

We found AVS occurred more frequently in malignant soft tissue tumors versus benign ones. Malignant soft tissue tumors also had more feeding arteries compared with benign tumors. These results were in consistent with previous publications.[12–14] Malignant soft tissue tumors generally grow faster than benign tumors, and require more blood supply. The vascular invasion is more serious in malignant tumors versus benign tumors. That is why malignant tumors have more feeding arteries and AVS.

The identification of many feeding arteries and AVS indicates malignant. If no AVS or feeding artery was identified, the tumor is likely benign.

This study had several limitations. First, the sample size was small. Soft tissue tumors in lower extremities are not conventionally evaluated with TWIST in clinical practice. More cases should be included in future study. Second, DSA is not used as the reference standard for determining tumor feeding arteries and AVS. DSA is invasive and expensive, so seldom used for diagnosis purpose for soft tissue tumors in lower extremities. Third, TWIST is not compared to time resolved CTA. Time resolved CTA exposes patients to much more ionizing radiation compared with conventional CTA. Such comparison might be performed in animal model in future.

In conclusion, feeding artery number and AVS derived from TWIST could be useful in discriminating benign from malignant soft tissue tumors.

Author contributions

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Funding acquisition: Gang Wu, Xiaoming Li.
Investigation: Gang Wu, Hao Yang.
Methodology: Gang Wu, Hao Yang, Xiaoming Li.
Project administration: Gang Wu, Hao Yang.
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Software: Gang Wu, Hao Yang, Xiaoming Li.
Supervision: Gang Wu, Hao Yang, Xiaoming Li.
Validation: Gang Wu, Hao Yang.
Visualization: Gang Wu, Hao Yang.
Writing – original draft: Hao Yang.
Writing – review & editing: Gang Wu, Xiaoming Li.

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