Quick Evaluation of Lower Leg Ischemia in Patients with Peripheral Arterial Disease by Time Maximum Intensity Projection CT Angiography: A Pilot Study

Daming Zhang  
Peking Union Medical College Hospital

Xueyan Zhou  
School of technology, Harbin University

Haiping Zhang  
Capital Medical University Affiliated Beijing Friendship Hospital Department of Radiology

Xiaobing Fan  
University of Chicago

Zehong Lin  
school of technology, harbin university

Huadan Xue  
Peking Union Medical College Hospital

Yining Wang  
Peking Union Medical College Hospital

Zhengyu Jin (jinzy@pumch.cn)  
Peking Union Medical College Hospital  https://orcid.org/0000-0002-6179-9632

Yuexin Chen  
Peking Union Medical College Hospital

Research article

Keywords: peripheral arterial disease, computed tomographic angiography, maximum intensity projection

DOI: https://doi.org/10.21203/rs.3.rs-81387/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

**Background:** The purpose of this study is to evaluate the new method of time maximum intensity projection (t-MIP) which was postprocessed from dynamic computed tomographic angiography (dyn-CTA) in diagnosing peripheral arterial disease (PAD).

**Methods:** A population of 34 patients with known PAD was examined with a combined CTA protocol consisting of an s-CTA of the lower extremity and a dyn-CTA scan of the calves. For each lower leg, t-MIP images consisting of the MIP<sub>0</sub> (sagittal MIP), and MIP<sub>±θ</sub> (45degree lateral MIP), MIP<sub>±θ</sub> (-45degree lateral MIP) were automatically generated from dyn-CTA. An objective evaluation of vascular CT attenuation of the best enhancement phase of dyn-CTA and t-MIP was measured; subjective evaluation of vessel stenosis and occlusion with a score was assigned for t-MIP and s-CTA. A comparison between the CT attenuation of t-MIP and dyn-CTA was made, so was the runoff score of t-MIP and s-CTA.

**Results:** The CT attenuation of t-MIP CTA of three vascular segments from 68 lower extremities was higher than that of the best enhancement phase of dyn-CTA and s-CTA, with statistical significant difference at posterior tibial artery and fibular artery (all \( p < 0.05 \)). There were strong correlations (\( r \geq 0.75, p < 0.05 \)) of runoff scores between t-MIP and s-CTA.

**Conclusions:** There is potential clinical application of t-MIP for assisting with the diagnosis of lower leg vascular stenosis in dyn-CTA with reliable diagnostic accuracy and convenient immediacy.

**Background**

Peripheral arterial disease (PAD) of lower extremity is frequently underdiagnosed [1], partly due to the wide variety of lower extremity symptoms that PAD patients exhibit and partly due to the high prevalence of asymptomatic PAD [2].

Currently, runoff computed tomographic angiography (CTA) of the peripheral vessels has become a widely used diagnostic option in patients with PAD. Runoff CTA which is also called standard CTA (s-CTA) is often incorporated into patients’ treatment planning because it is accessible, quick and relatively inexpensive. CTA can provide morphology of lower extremity arteries to diagnose PAD [3]. However, the diagnostic accuracy of vessel stenosis is still a challenge in some clinical conditions, such as severe calcification [4], the inaccurate timing of contrast bolus due to the long-distance vessels of lower extremity, asymmetric proximal stenoses or abnormal cardiac function [5].

Dynamic CTA (dyn-CTA) of the lower extremities offers a solution for patients with diagnostic inaccuracy problems using s-CTA [6]. In recent years, as new examination techniques, continuous bidirectional table movements make dynamic volume coverage in an area up to 45 cm long and achieve whole dynamic imaging of the lower legs [7]. The feasibility studies of dyn-CTA of vessels beneath knees provide promising results [8]. Compared with s-CTA, dyn-CTA shows better performance on arterial contrast enhancement, diagnostic confidence, and diagnostic accuracy for detecting vessel stenoses and
occlusions in PAD patients [9]. Buls et al. evaluated the mean CT values (HU) of all arteries below the knees, and gave conclusion that dyn-CTA showed higher image quality and diagnostic confidence for assessing the occurrence and degree of arterial stenosis [10].

Most existing studies on dyn-CTA require multiphase data review, which is time-consuming compared with s-CTA and limits the clinical application of dyn-CTA. Maximum intensity projection (MIP) was introduced for clinical use with CTA [11] and it is widely used in vascular imaging of the whole body [12–15]. Time MIP (t-MIP) images reflect the maximum value of each matrix in the dynamic data for all time phases. It was first described by Murayama et al.[16] for early ischemic changes in patients with acute ischemic stroke. T-MIP was shown to have a better signal noise ratio in white and grey matter of brain than single-phase CTA [16, 17]. To date, there have been no studies on t-MIP achieved from dyn-CTA facilitating diagnosis of PAD.

In this study, we used t-MIP CTA to provide an intuitive, fast and noninvasive solution for the diagnosis of lower extremity stenosis diagnosis. The aim of this study was to assess the diagnostic accuracy t-MIP CTA postprocessed from dyn-CTA in comparison to s-CTA.

**Methods**

**Patients**

The Institutional Review Board of Peking Union Medical College Hospital approved this study (HS-934). From November 2015 to March 2016, 35 patients with known PAD were included. One patient was excluded for severe calcified plaques and motion artifact. Thirty-four patients (average age=65.4±11.6 years old; 11 females, 23 males; average body mass index=23.2±3.0) with 68 lower extremities and 204 vascular segments were analyzed.

**CTA Protocols**

A third-generation dual-source dual-energy CT system (Somatom Definition Force, Siemens Healthcare, Forchheim, Germany) was used to perform the scan. The protocol was previously described in study on lower leg muscle ischemia evaluation by Zhou et al. [18]. It was consisted of dyn-CTA and s-CTA. First was dyn-CTA of the lower legs with a 45 cm scan range using a shuttle mode. The scan parameters were tube voltage 70 kV, tube current 80 mA and collimation with 2×64×0.6 mm. There were 9 phases of the dyn-CTA scan. The first 5 phases were 2.5 s/phase and the last 4 phases were 5 s/phase. The data acquisition time was 30s in total. A soft convolution kernel (Bv40) reconstructed images were rendered with a slice thickness of 1.5 mm and increment of 1 mm for all 9 acquisition phases. 30 mL contrast media (iopromide 370 mgI/mL)was injected at a flow rate of 4.0 mL/s and a saline bolus of 50 mL/s followed at the same flow rate.

S-CTA was performed five minutes later. The scan parameters [19] were tube voltage 70kV, tube current 322 mA; pitch 0.6; rotation time 0. 25s and collimation with 2×64×0. 6 mm. 50 mL contrast agent
(iopromide 370 mg/mL) was administered intravenously at a flow rate of 2.5 mL/s, and 40 mL saline water followed at the same flow rate. S-CTA used the bolus tracking technique by placing the region of interest (ROI) at the healthy popliteal artery. When a threshold reached 100 HU the scan started automatically after 6 s. A soft convolution kernel (Bv40) reconstructed images were rendered with a 1.5 mm slice thickness and 1 mm increment.

**CT radiation dose**

To estimate the CTA radiation dose, the volume CT dose index (CTDIfvol) and the dose length product (DLP) from the dose report of each patient was documented. Since there was no conversion coefficients k for the effective dose of CTA in the lower extremities of 70 kV, no effective dose was calculated [20].

**Data postprocessing**

Dyn-CTA MIP generation was performed using MATLAB R2017a (MathWorks, Natick, MA) with in-house software. DICOM data were loaded into the software. To ensure getting clear vascular images, 1.5 mm thick data were used for analysis, with 453 slices in total. First, the patient bed was removed from the source data. Then, bone was automatically removed from the source data by using the threshold value of 5 times the average CT attenuation of the whole image. The maximum value of each matrix was reserved for vasculature, muscle and fat. All phase images were arranged in line and merged into one large matrix. Finally, for each lower extremity, the axial images and three t-MIP images (figure 1) - MIP₀ (sagittal MIP), MIP₀⁺θ (45 degree lateral MIP), MIP₀⁻θ (-45 degree lateral MIP) were automatically generated from the large matrix for diagnosis. The analysis process attempts to avoid the interference of human factors. The images were processed by a single medical physicist who was blinded to the patient groupings.

**Data analysis**

**Objective analysis**

The CT attenuation of three lower extremity artery segments (anterior tibial artery, posterior tibial artery and fibular artery) was measured by one radiologist (DZ, 8-year experience) on axial images of t-MIP CTA, the best enhancement phase of dyn-CTA and s-CTA. Region of interests (ROIs) were placed at the proximal 1/3 of the lower legs with the same slice for t-MIP CTA, dyn-CTA and s-CTA.

**Subjective analysis**

For each of three lower extremity artery segments, stenosis percentage and occlusion length were evaluated in the form of a runoff score. This score ranged from 0 to 9, with a higher score indicating more severe disease. For each of three lower extremity artery segments, a score was assigned as follows: 0, no-20% stenosis; 1, 21-49% stenosis; 2, 50-99% stenosis, 2.5, half of the vessel length occluded; 3, half of the vessel length occluded. All 3 vessel scores were added together to achieve the runoff score for the lower extremity [21].
The scores were provided by two vascular imaging radiologists (DZ and HZ, 3-year experience). The s-CTA image was first evaluated, to ensure that the memory washout was acquired. Four weeks later, t-MIP CTA were provided to two vascular imaging radiologists, and they gave scores with the same evaluation criteria respectively.

According to the runoff score of s-CTA, 68 lower legs were divided into a normal group (n = 24) with each vessel segment score ≤1 and runoff score ≤2 and an abnormal group with vascular stenosis (n = 44).

**Statistical Analyses**

All statistical analyses were performed using the Statistical Package for Social Sciences, version 19.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as the mean ± standard deviation (SD). The difference of numerical data sets among three groups was tested by using ANOVA. When the result of ANOVA was significant, Tukey’s Honest Significant Distant (HSD) procedure was used for the multiple comparisons between the three groups in pairwise manner. Kruskal-Wallis rank sum test was used to test the difference of non-normal distributed data among three groups. When the result of Kruskal-Wallis test was significant, Mann-Whitney U test was used for pairwise comparison. The categorical data was compared with the paired Wilcoxon test. A Bland-Altman outlying plot was used to assess the consistency of runoff scores between t-MIP and s-CTA. Numbers that were within plus or minus the standard deviation of 1.96 were usually not emphasized. A p-value less than 0.05 was considered significant. Interobserver agreement- Cronbach’s alpha (α) was calculated for measuring interobserver agreement among the two radiologists.

**Results**

The indication for CTA was limb ischemia (Fontaine stage I, n=6; Fontaine stage II, n=19; Fontaine stage III, n=3; and Fontaine stage IV, n=6). The mean ± SD of CTDIvol and DLP were 9.1 ± 0.0 mGy and 396.9 ± 0.1 mGy × cm for dyn-CTA and 1.6 ± 0.3 mGy and 212.4 ± 41.5 mGy × cm for s-CTA respectively.

In clinical practice, it is difficult to acquire satisfied MIP images for patient with asymmetric vascular stenosis and different peak enhancement times of lower extremities. Different phase of dyn-CTA achieves peak enhancement of different segments of lower extremities vessels. T-MIP merges all phases of dyn-CTA and generates the optimal enhancement for both proximal and distal vessels (figure 2).

**Objective analysis**

The CT attenuation of t-MIP CTA of three vascular segments from 68 lower extremities was higher than that of the best enhancement phase of dyn-CTA and s-CTA (Table 1). For CT attenuation of anterior tibial artery, there was no significant difference between three groups (p=0.135). While for posterior tibial artery and fibular artery, there was significant difference between CT attenuation of t-MIP CTA and s-CTA (all p<0.05). For average CT attenuation of anterior tibial artery, posterior tibial artery and fibular artery, there was significant difference between t-MIP CTA and s-CTA, as well as dyn-CTA and s-CTA (all p<0.05).
Subjective analysis

There was good interobserver agreement in the assigned runoff score based on t-MIP images between the two radiologists ($\alpha = 0.833$).

Runoff scores evaluated with t-MIP and s-CTA were correlated for both radiologist A ($r=0.75$, $p<0.001$) and radiologist B ($r=0.78$, $p<0.001$) (figure 3). The results of Bland-Altman analysis are summarized in Table 2, showing a mean difference of 1.79 and 95% limits of agreement of -2.32 to 5.91 for radiologist A as well as a mean difference of 1.38 and limits of agreement of -2.55 to 5.30 for radiologist B. The runoff score per leg with s-CTA was $3.7\pm3.2$. Compared to that with s-CTA, the runoff score per leg with t-MIP for radiologists A and B was significantly different (radiologist A, $5.6\pm2.3$, $p=0.000$; radiologist B, $5.1\pm2.3$, $p=0.000$).

The patient’s runoff score was higher when he or she was at severer clinical stage for both s-CTA and t-MIP (table 3). For radiologist B, the t-MIP runoff score was significantly higher ($p=0.034$) for patient under Fontaine stage III+ IV than those under Fontaine stage I+ II. While for s-CTA runoff score and t-MIP runoff score given by radiologist A, there was no significant difference between patients under Fontaine stage I+ II and Fontaine stage III+ IV.

Discussion

The evaluation of lower extremity vascular stenosis using t-MIP was feasible based on the results of this study. There was a strong correlation of the runoff score between t-MIP and s-CTA. T-MIP images automatically retrieved and merged the maximal CT attenuation of lower leg arteries from the multiple phases of CTA data and provided an intuitive and clear view used for diagnosis.

Studies on dyn-CTA have shown that compared with s-CTA, dyn-CTA can improve arterial enhancement and diagnostic confidence [9, 10], which may compensate for the limitation of unsatisfactory arterial enhancement of lower extremity runoff CTA. In addition to the advantage of tracking the best time of the bolus, large image data of multiphase dyn-CTA consume more time than those of s-CTA and inhibit its clinical application.

T-MIP is a technique derived from head CT perfusion that reflects the maximum value on all projection planes at all time points from CTP [16]. A previous study showed that t-MIP colored images had the best discriminative value (area under curve, 0.811) for the detection of early ischemic changes compared with CT perfusion cerebral blood volume images, gray images of t-MIP and noncontrast CT (NCCT)[16]. Another study conducted by Cao et. al. showed that t-MIP images showed higher vascular attenuation than s-CTA images, and were more predictable for acute ischemic stroke[17].

According to our knowledge, there have been no previous studies using t-MIP in lower extremity dyn-CTA, and there is no commercial software that can postprocess lower extremity dyn-CTA images into t-MIP images. Our study is the first to apply t-MIP in PAD diagnosis. In this study, The CT attenuation of anterior
tibial artery, posterior tibial artery and fibular artery at proximal 1/3 of the lower legs in t-MIP images was 21.5 to 28.3 HU higher than that in best enhancement phase of dyn-CTA, and was 50.5 to 56.1 HU higher than that in s-CTA images. It was reasonable for t-MIP retrieved the highest vascular attenuation from the whole time-phase of dyn-CTA images, and the previous study found that t-MIP[17] and dyn-CTA [10] showed higher vascular attenuation than s-CTA. In our study, t-MIP was correlated with s-CTA, which was consistent with the results of the previous study and a follow up [16] showing that t-MIP images had a strong positive correlation with NCCT images. Although we used t-MIP to postprocess the dyn-CTA data, the higher diagnostic performance of dyn-CTA was reserved in t-MIP images. Sommer et. al.[9] reported that compared to s-CTA, dyn-CTA had higher a sensitivity and specificity for detecting stenosis and occlusion. In this study, the average runoff score of t-MIP was higher than that of s-CTA, which indicates a severe level of stenosis or occlusion.

The application of dyn-CTA of the lower extremities was also restricted by the long scan range and high radiation dose. A recent CT scanner provides dynamic CTA with scan ranges up to 60 cm in length with the shuttle mode, which is helpful for lower leg dyn-CTA. In addition to a longer scan range, the tube voltage of 70 kV was workable in runoff CTA to reduce the radiation dose in previous studies [22, 23], as well as 45 mL of contrast medium, which was less than half the amount of routine runoff CTA [22]. In this study, a low tube voltage of 70 kV for dyn-CTA made the DLP 396.9 ± 0.1 mGy × cm. The contrast medium volume was relatively large for the lower extremities. To prevent renal function impairment [24], the contrast medium was reduced to 30 mL for dyn-CTA and 50 mL for s-CTA. The DLP and contrast amount of 80 mL in total made the protocol combining dyn-CTA and runoff CTA more applicable in clinical practice.

There were several limitations to this study. First, the population of patients was small which made subgroups based on different clinical stages impossible. Further studies should involve more patients, especially patients with Fontaine stage III and IV, for whom the contrast bolus time may be more likely abnormal. Second, the runoff score of t-MIP was only compared with that of s-CTA, and the gold-standard analysis was lacking. This was partly caused by the small patient population, and the numbers of patients with a severe clinical stage was small. Third, the postprocessed images of t-MIP not only retrieved the highest vascular CT attenuation but also selected muscle CT attenuation. Although the enhancement of muscle was mild, it may still lower the contrast to noise ratio of t-MIP.

Conclusions

In conclusion, there is potential clinical application of t-MIP for assisting with the diagnosis of lower leg vascular stenosis in dyn-CTA with reliable diagnostic accuracy compared to s-CTA and with convenient immediacy compared to dyn-CTA. Therefore, t-MIP is a powerful noninvasive and quick diagnostic method that can be used in the treatment plans of PAD patients.

Declarations
Ethics approval and consent to participate

This study was approved by the Institutional Review Board at our institution (HS-934)

Consent for publication

Not applicable

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the National Public Welfare Basic Scientific Research Program of Chinese Academy of Medical Sciences (2018PT32003 and 2017PT32004) in the design of the study and collection, analysis, and Peking Union Medical College Hospital Youth funding (pumch201911061) in interpretation of data and writing.

Authors' contributions

DZ analyzed the data and drafted the manuscript

XZ created the code to retrieve the time maximum intensity projection images and drafted the manuscript

HZ analyzed the data

XF designed the research and revised the manuscript

ZL revised the image processing code

HX designed the research

YW participated in images acquisition

ZJ designed the research and revised the manuscript

YC participated in images acquisition

Acknowledgements

Not applicable
References

1. Patel AY, Gurm HS: Medical Management of Lower Extremity Peripheral Artery Disease. In: Practical Approach to Peripheral Arterial Chronic Total Occlusions. edn.: Springer; 2017: 1-8.

2. Dua A, Lee CJ: Epidemiology of Peripheral Arterial Disease and Critical Limb Ischemia. Techniques in vascular and interventional radiology 2016, 19(2):91-95.

3. Preuss A, Schaafs LA, Werncke T, Steffen IG, Hamm B, Elgeti T: Run-Off Computed Tomography Angiography (CTA) for Discriminating the Underlying Causes of Intermittent Claudication. PloS one 2016, 11(4).

4. Pollak AW, Norton PT, Kramer CM: Multimodality imaging of lower extremity peripheral arterial disease: current role and future directions. Circ Cardiovasc Imaging 2012, 5(6):797-807.

5. Keeling AN, Farrelly C, Carr JC, Yaghmai V: Technical considerations for lower limb multidetector computed tomographic angiography. Vascular medicine 2011, 16(2):131-143.

6. Werncke T, Ringe KI, von Falck C, Kruschewski M, Wacker F, Meyer BC: Diagnostic Confidence of Run-Off CT-Angiography as the Primary Diagnostic Imaging Modality in Patients Presenting with Acute or Chronic Peripheral Arterial Disease. PloS one 2015, 10(4).

7. Sommer WH, Helck A, Bamberg F, Albrecht E, Becker CR, Weidenhagen R, Kramer H, Reiser MF, Nikolaou K: Diagnostic value of time-resolved CT angiography for the lower leg. European radiology 2010, 20(12):2876-2881.

8. Kortman HGJ, Smit EJ, Oei MTH, Manniesing R, Prokop M, Meijer FJA: 4D-CTA in Neurovascular Disease: A Review. Am J Neuroradiol 2015, 36(6):1026-1033.

9. Sommer WH, Bamberg F, Johnson TR, Weidenhagen R, Notohamiprodjo M, Schwarz F, Reiser MF, Nikolaou K: Diagnostic accuracy of dynamic computed tomographic angiographic of the lower leg in patients with critical limb ischemia. Investigative radiology 2012, 47(6):325-331.

10. Buls N, de Brucker Y, Aerden D, Devos H, van Gompe G, Boonen PT, Nieboer K, Leiner T, de Mey J: Improving the diagnosis of peripheral arterial disease in below-the-knee arteries by adding time-resolved CT scan series to conventional run-off CT angiography. First experience with a 256-slice CT scanner. European journal of radiology 2019, 110:136-141.

11. Napel S, Marks MP, Rubin GD, Dake MD, McDonnell CH, Song SM, Enzmann DR, Jeffrey RB, Jr.: CT angiography with spiral CT and maximum intensity projection. Radiology 1992, 185(2):607-610.

12. Galanski M, Prokop M, Chavan A, Schaefer CM, Jandeleit K, Nischelsky JE: Renal arterial stenoses: spiral CT angiography. Radiology 1993, 189(1):185-192.

13. Iglesias J, Pena C: Computed tomography angiography and magnetic resonance angiography imaging in critical limb ischemia: an overview. Techniques in vascular and interventional radiology 2014, 17(3):147-154.

14. Jeong YJ, Lee KS, Yoon YC, Kim TS, Chung MJ, Kim S: Evaluation of small pulmonary arteries by 16-slice multidetector computed tomography: Optimum slab thickness in condensing transaxial images
converted into maximum intensity projection images. Journal of computer assisted tomography 2004, **28**(2):195-203.

15. Randoux B, Marro B, Koskas F, Duyme M, Sahel M, Zouaoui A, Marsault C: **Carotid artery stenosis: prospective comparison of CT, three-dimensional gadolinium-enhanced MR, and conventional angiography.** Radiology 2001, **220**(1):179-185.

16. Murayama K, Suzuki S, Matsukiyo R, Takenaka A, Hayakawa M, Tsutsumi T, Fujii K, Katada K, Toyama H: **Preliminary study of time maximum intensity projection computed tomography imaging for the detection of early ischemic change in patient with acute ischemic stroke.** Medicine 2018, **97**(9):e9906.

17. Cao R, Jiang Y, Lu J, Wu G, Zhang L, Chen J: **Evaluation of Intracranial Vascular Status in Patients with Acute Ischemic Stroke by Time Maximum Intensity Projection CT Angiography: A Preliminary Study.** Academic radiology 2019.

18. Zhou X, Zhang D, Zhang H, Lin Z, Fan X, Jin Z: **Quantitative Analysis of Lower Leg Muscle Enhancement Measured From Dynamic Computed Tomographic Angiography for Diagnosis of Peripheral Arterial Occlusive Disease.** Journal of computer assisted tomography 2020, **44**(1):20-25.

19. Qi L, Meinel FG, Zhou CS, Zhao YE, Schoepf UJ, Zhang LJ, Lu GM: **Image quality and radiation dose of lower extremity CT angiography using 70 kVp, high pitch acquisition and sinogram-affirmed iterative reconstruction.** PloS one 2014, **9**(6):e99112.

20. Saltybaeva N, Jafari ME, Hupfer M, Kalender WA: **Estimates of effective dose for CT scans of the lower extremities.** Radiology 2014, **273**(1):153-159.

21. Stoner MC, Calligaro KD, Chaer RA, Dietzek AM, Farber A, Guzman RJ, Hamdan AD, Landry GJ, Yamaguchi DJ, Society for Vascular S: **Reporting standards of the Society for Vascular Surgery for endovascular treatment of chronic lower extremity peripheral artery disease.** Journal of vascular surgery 2016, **64**(1):e1-e21.

22. Horehledova B, Mihl C, Milanese G, Brans R, Eijsvoogel NG, Hendriks BMF, Wildberger JE, Das M: **CT Angiography in the Lower Extremity Peripheral Artery Disease Feasibility of an Ultra-Low Volume Contrast Media Protocol.** Cardiovascular and interventional radiology 2018, **41**(11):1751-1764.

23. Qi L, Zhao Y, Zhou CS, Spearman JV, Renker M, Schoepf UJ, Zhang LJ, Lu GM: **Image quality and radiation dose of lower extremity CT angiography at 70 kVp on an integrated circuit detector dual-source computed tomography.** Acta radiologica 2015, **56**(6):659-665.

24. Andreucci M, Faga T, Pisani A, Sabbatini M, Michael A: **Acute kidney injury by radiographic contrast media: pathogenesis and prevention.** BioMed research international 2014, **2014**:362725.

**Tables**

Table 1 CT attenuation of anterior tibial artery, posterior tibial artery and fibular artery of t-MIP, best enhancement phase of dyn-CTA and s-CTA
| CT attenuation (HU) | t-MIP     | Dyn-CTA   | s-CTA     |
|---------------------|-----------|-----------|-----------|
| Anterior tibial artery | 375.6±148.0 | 347.3±120.4 | 319.5±112.6 |
| Posterior tibial artery | 371.1±105.9 | 344.6±101.9 | 320.6±97.8 |
| Fibular artery        | 343.8±94.0  | 322.3±108.3 | 287.5±107.4 |
| Average              | 363.4±117.9 | 337.6±110.3 | 308.5±106.1 |

t-MIP, time maximum intensity projection; dyn-CTA, dynamic computed tomographic angiography; s-CTA, standard computed tomographic angiography

**Table 2. Comparison between t-MIP and s-CTA runoff scores using Bland-Altman analysis**

|                        | Radiologist A | Radiologist B |
|------------------------|---------------|---------------|
| Correlation            |               |               |
| r                      | 0.75          | 0.78          |
| p                      | <0.001        | <0.001        |
| Regression line        |               |               |
| slope                  | 0.54          | 0.57          |
| $y_0$                  | 3.49          | 3.01          |
| Difference (t-MIP-s-CTA) |             |               |
| mean±SD                | 1.79±2.10     | 1.38±2.00     |
| 95% LA                 | -2.32 to 5.91 | -2.55 to 5.30 |
| SEM                    | 0.47          | 0.43          |
| 95% CI                 | 1.29 to 2.30  | 0.89 to 1.86  |
| bias                   | yes           | yes           |

t-MIP, time maximum intensity projection; s-CTA, standard computed tomographic angiography; SD, standard deviation; 95% LA, 95% limits of agreement; SEM, standard error of the mean difference; 95% CI; 95% confidence interval

**Table 3. Runoff score and clinical stage of t-MIP and s-CTA**

| Runoff score | Fontaine stage I+ II | Fontaine stage III+ IV |
|--------------|----------------------|------------------------|
| t-MIP radiologist A | 5.7±2.0             | 7.1±2.3               |
| t-MIP radiologist B | 5.0±2.2             | 6.6±2.3               |
| s-CTA        | 3.6±3.2              | 5.9±3.5               |

t-MIP, time maximum intensity projection; s-CTA, standard computed tomographic angiography
Figures

Figure 1

The schematic diagram and case of dyn-CTA of lower legs of MIP (figure A) and t-MIP (figure B) technique. MIP reserved maximum value of one matrix. For t-MIP, maximum value of each matrix at each time point of dyn-CTA was reserved and merged into one large matrix. dyn-CTA, dynamic computed tomographic angiography; t-MIP, time maximum intensity projection.
Figure 2

Comparison of t-MIP CTA and different phases of dyn-CTA of the lower extremities: A 37-year-old male patient with ischemia of the right lower extremity and normal left lower extremity. Figure A shows t-MIP images, and the proximal and distal vessel segments of the arteries of the lower legs showed optimal enhancement. Figure B and figure C show the MIP images of the second and third phases of dyn-CTA. The proximal vessel segments were more enhanced in the second phase, while the distal vessel segments were more enhanced in the third phase. 0, sagittal position; +6, 45 degree lateral position; -6, -45 degree lateral position.

Figure 3

Comparison of runoff scores between t-MIP and s-CTA: Figure A, B. regression curve, runoff score of t-MIP by radiologist A=0.54, runoff score of s-CTA=3.49; r= 0.75; p< 0.001. Runoff score of t-MIP by radiologist B=0.57, runoff score of s-CTA=3.01; r=0.78; p< 0.001. Figure C, D. Bland-Altman plots, horizontal lines indicate the mean difference and 95% limits of agreement (95% LAs).