International Journal of Nursing Sciences 5 (2018) 45–49

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Contents lists available at ScienceDirect

International Journal of Nursing Sciences

journal homepage: http://www.elsevier.com/journals/international-journal-of-nursing-sciences/2352-0132

Original Article

Investigation and analysis of lower extremity arterial disease in hospitalized elderly type 2 diabetic patients

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ARTICLE INFO

Article history:
Received 27 February 2017
Received in revised form
29 June 2017
Accepted 25 October 2017
Available online 19 January 2018

Keywords:
Aged
Ankle-brachial index
Diabetes mellitus, type 2
Diabetic angiopathies
Hospitalized
Lower extremity arterial disease

ABSTRACT

Background: The risk of lower extremity arterial disease (LEAD) is increased in diabetic patients. LEAD in diabetic patients occurs earlier and is often more severe and diffuse; however, it is largely underdiagnosed and untreated. The purposes of this study were to investigate and analyze LEAD situation of hospitalized elderly type 2 diabetic patients.
Methods: The ankle–brachial index (ABI) was used to screen LEAD in hospitalized elderly type 2 diabetic patients. The patients were divided into 5 groups based on the screening results: non-LEAD group and LEAD group; the LEAD group was divided into mild stenosis group, moderate stenosis group, and severe stenosis group.
Results: The percentage of patients who had LEAD was 43%. Significant difference in age, diabetes duration, peak velocity, microalbuminuria, and vibratory sensory neuropathy was observed between patients with and without LEAD; regression analysis showed that urinary albumin and vibratory sensory neuropathy were independent risk factors for LEAD. Significant difference in age, body mass index (BMI), peak velocity, urinary albumin, and high-density lipoprotein cholesterol (HDL-C) was observed between mild stenosis group, moderate stenosis group, and severe stenosis group; regression analysis showed that urinary albumin, BMI, and HDL-C were independent risk factors for accelerating vascular stenosis.
Conclusions: The incidence of LEAD in hospitalized elderly type 2 diabetic patients is high; age, diabetes duration, peak velocity, BMI, urinary microalbumin, vibratory sensory neuropathy, and HDL-C are the major risk factors for LEAD. Active control of risk factors is helpful to reduce or delay LEAD.

1. Introduction

Lower extremity arterial disease (LEAD) is a chronic atherosclerotic occlusive disease that occurs in the lower extremities. It occurs earlier in diabetic than in nondiabetic individuals and is often more severe, diffuse, and popular [1,2]. In comparison with nondiabetic subjects, patients with diabetes have a twofold increased risk of developing LEAD [3,4]. In the United Kingdom Prospective Diabetes Study, 1.2% of nearly 5000 individuals with newly diagnosed type 2 diabetes had LEAD at the time of diagnosis [5]. Although LEAD is common, most of the cases are asymptomatic and underdiagnosed [6], especially in elderly diabetic populations [7]. The presence of LEAD increases the risk of claudication, ischemic ulcers, gangrene, and possible amputation. Apart from this, LEAD patients, whether they are symptomatic or asymptomatic, have an increased risk of death and cardiovascular events because of the coexisting clinical or subclinical atherosclerosis in the coronary and the cerebral arteries [8]. Studies revealed that mortality is cardiovascular related in approximately 75% [2], and the 5-year survival rate of LEAD patients with diabetes is just about 50% [9]. Therefore, screening for LEAD is strongly encouraged in every patient with diabetes to optimize medical treatment in this specific population [2].

Ankle–brachial index (ABI), defined as the ratio of systolic pressure in the ankle arteries (the highest one among the dorsalis pedis arterial systolic pressure and the posterior tibial arterial systolic pressure) and systolic pressure in the brachial artery, is an important, noninvasive, and practical measurement for the detection of arterial obstructive disease, especially for LEAD [10]. ABI has a validated sensitivity and specificity in detecting LEAD which is

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Peer review under responsibility of Chinese Nursing Association.

https://doi.org/10.1016/j.ijnss.2017.10.020

alternative to conventional digital subtraction angiography [11]. Decrinis [12] et al. strongly proved the validity of ABI in detecting arterial stenoses in lower extremity, and revealed that the sensitivity and specificity of ABI were respectively 94% and 100%.

However, despite the recognition that LEAD is associated with a three- to sixfold increased risk of death from cardiovascular causes [13], particularly in diabetic patients, this specific manifestation of systemic atherosclerosis is largely underdiagnosed and undertreated [2]. Hence, this study aims to investigated LEAD in hospitalized elderly type 2 diabetic patients and analyze the risk factors to provide possible evidence for intervention.

2. Methods

2.1. Subjects

From May 2013 to June 2014, hospitalized elderly patients with type 2 diabetes mellitus were investigated at Huadong Hospital in Shanghai, China. The inclusion criteria were (1) diagnosed with elderly type 2 diabetes based on the criteria of Chinese Medical Association Diabetes Branch and (2) conscious and voluntarily participated in the research. The exclusive criteria were (1) with past lower limb amputation history, (2) presented serious lower limb edema, and (3) presented lower limb skin damage. Informed consent was obtained from each patient included in the study. A total of 237 patients were enrolled (120 males, 117 females), mean age was 71.4 ± 7.9 years old, and mean duration of diabetes was 12.8 ± 9.3 years.

2.2. Demographic information and biochemical parameters

As part of the standard clinical evaluation of each patient, the following demographic data were compiled for this study: age, gender, duration of diabetes, height and weight (for the calculation of body mass index [BMI]), presence of hypertension, and so on. A finding of $18.5 \leq$ BMI < 24 kg/m^2 was considered normal. Hypertension was defined as systolic blood pressure $\geq$140 mmHg and/or diastolic blood pressure $\geq$90 mmHg or if the patient was receiving antihypertensive treatment [14]. All subjects underwent assessments of a range of clinical and biochemical variables. Venous blood samples for serum total cholesterol (TCH), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), glycated hemoglobin (HbA1c), and glycated albumin (GA) were collected. Microalbuminuria was measured by random daytime urine sample. Microalbuminuria was defined entirely by calculation of albumin-to-creatinine ratio in urine specimen. The normal range of each parameter are as follows: TCH < 5.72 mmol/L, TG < 1.70 mmol/L, LDL-C < 3.64 mmol/L, HDL-C < 1.29 mmol/L in females and <1.03 mmol/L in males, HbA1c 4.0%–6.0%, GA 11.0%–17.0%, microalbuminuria <2.26 mg/mmol·Cr [14,15].

2.3. LEAD screen

The ABI values were measured by using Doppler blood stream probe (Bidop ES-100V3, Hadeco, Japan). All the ABI measurements were performed with the subjects in the supine position after the participants rested in a supine position for 10 min in a temperature-controlled (23–25 °C) and quiet room. A blood pressure cuff was placed on subjects' upper arms, and it was inflated until no brachial pulse was detected by the Doppler device. Then, the cuff was slowly deflated until the Doppler detected that the pulse returned (the systolic pressure). This methodology was repeated on the legs to measure the dorsalis pedis and the posterior tibial arterial systolic pressure [16]. The higher systolic pressure in the dorsalis pedis and the posterior tibial arteries serves as ankle systolic pressure. The ABI was calculated by dividing the ankle systolic pressure by the higher brachial systolic pressure [16]. ABI > 1.3 increased, thereby suggesting arteriosteogenesis; $0.9 <$ ABI ≤ 1.3 was normal; ABI ≤ 0.9 was reduced, suggesting LEAD; $0.7 <$ ABI ≤ 0.9 suggested mild vascular stenosis; $0.4 <$ ABI ≤ 0.7 suggested moderate vascular stenosis; ABI ≤ 0.4 suggested severe vascular stenosis [17]. Patients with ABI > 1.3 were excluded because such results usually reflect arterial rigidity, preventing arterial compression; diagnosis of LEAD was based on ABI < 0.9 on either leg. Patients were divided into 4 groups based on the screening results: non-LEAD group and LEAD group; the LEAD group was divided into mild stenosis group, moderate stenosis group, and severe stenosis group. Peak velocity, which was measured by Doppler blood stream probe, is the maximum velocity in the cross-sectional area of the blood vessel when the heart is contracted, thereby reflecting the extent of arterial stenosis.

2.4. Peripheral neuropathy examination

Diabetic peripheral neuropathy was diagnosed on the basis of typical symptoms and peripheral sensory nerve function examination in the feet, including the nylon filament test for diminished or no pressure sensation, temperature sense examination tool for abnormal temperature sensation, and 128 Hz tuning fork for abnormal vibrations. The 128 Hz tuning fork was applied twice at the back of the fist metatarsal. Vibration sensation was abnormal if patients did not perceive the vibration sensation either time. In the pressure sensation examination, five positions of the foot were screened, including the first toe, the first and fifth metatarsal, the arch of the foot, and heel (avoid the corpus callosum). A 10 g nylon monofilament was vertically pressed at those five positions, lasting 1–2 s, and the patients were then asked whether they feel pressure. Patients had abnormal pressure sensation if pressure on 2 or more positions cannot be felt. The temperature sense examination tool, whose one end is metal and another one is polyester, was used to test abnormal temperature sensation. The examination positions and the judging of temperature sensation is the same with pressure sensation. Besides, populations were considered having peripheral neuropathy if they have obvious neuropathy symptoms.

2.5. Statistical analysis

All statistical analyses were performed using SPSS (the statistical package for social science program, Windows, version 17.0). Continuous variables were presented as mean ± standard deviation. Categorical variables were expressed as a percentage. The independent-samples *t*-test and one-way analysis of variance were used to examine continuous variables, the chi-square test and rank test were used to examine categorical differences. All parameters were first analyzed by univariate analysis, and those significantly differing were enrolled in multiple logistic regression with forward stepwise procedure to identify independent risk factors. Difference between values were considered statistically significant when $P < 0.05$.

3. Results

3.1. Clinical characteristics

This study included 237 hospitalized elderly type 2 diabetic patients. The male/female ratio was 120/117, the mean age was 71.4 ± 7.9 years old, the mean BMI was 24.7 ± 3.7 kg/m^2, the mean diabetes duration was 12.8 ± 9.3 years, the mean hypertension duration was 10.8 ± 11.8 years, the mean HbA1c level was

8.1 ± 2.1%, and the mean GA level was 23.2 ± 8.8%. The mean level of TCH, TG, HDL-C, and LDL-C were 4.7 ± 1.4, 2.4 ± 4.4, 1.4 ± 1.0, and 2.6 ± 0.9 mmol/L, respectively. The percentages of microalbumin, abnormal vibration, pressure, and temperature sense were 45.6%, 46.8%, 9.5%, and 72.8%, respectively (Table 1).

3.2. Prevalence of LEAD

In this study, 135 (57%) of 237 hospitalized elderly type 2 diabetic patients did not have LEAD, 102 (43%) patients had LEAD; of the 102 patients with LEAD, 69 (67.6%) subjects had mild stenosis, 28 (27.5%) subjects had moderate stenosis, and 5 (4.9%) subjects had severe stenosis. Clinical characters of LEAD patients are shown in Table 1.

3.3. Risk factors for LEAD

The results of univariate analysis revealed that patients with and without LEAD significantly differed in age, diabetes duration, peak velocity, microalbuminuria, and vibratory sensory neuropathy. Patients with LEAD were older (73.0 ± 8.5 years vs. 70.1 ± 7.2years, $P = 0.05$), had longer diabetes duration (14.2 ± 10.0 years vs. 11.7 ± 8.6 years, $P = 0.037$), had lower peak velocity (23.8 ± 13.3 cm/s vs. 29.7 ± 14.4 cm/s), had more microalbuminuria percentage (53.9% vs. 39.3%) and had more vibratory sensory neuropathy percentage (52.0% vs. 30.4%) (Table 1).

Variables considered for multivariate logistic regression models with forward stepwise procedure were based on the findings of univariate analysis. The results of statistical analysis revealed that microalbuminuria (OR 1.8, 95% CI 1.0–3.3, $P = 0.04$) and vibratory sensory neuropathy (OR 2.2, 95% CI 1.2–3.9, $P = 0.008$) were independent risk factors for LEAD (Table 2).

3.4. Risk factors for promoting LEAD

Table 1 shows the significant difference in age, BMI, peak velocity, microalbuminuria, and HDL-C between mild stenosis patients, moderate stenosis patients, and severe stenosis patients. Patients had more severe stenosis, were older (71.6 ± 8.0 years old vs. 75.7 ± 9.2 years vs. 77.2 ± 5.8 years old, P = 0.007), had lower BMI (24.3 ± 3.7 kg/m^2 vs. 24.4 ± 2.8 kg/m^2 vs. 22.0 ± 1.7 kg/m^2, $P = 0.025$), had lower peak velocity (26.7 ± 12.7 cm/s vs. 19.1 ± 12.7 cm/s vs. 9.6 ± 6.6 cm/s, $P = 0.001$), had lower HDL-C level (1.5 ± 1.5 mmol/L vs. 1.1 ± 0.3 mmol/L vs. 0.9 ± 0.3 mmol/L, $P = 0.035$), and had higher microalbuminuria percentage (46.4% vs. 64.3% vs. 100%, $P = 0.029$) (Table 1).

On the basis of the outcome of the univariate analysis, multivariate logistic regression with the forward stepwise procedure was performed, with results showing that BMI (OR 1.4, 95% CI 1.0–1.8, $P = 0.0001$), HDL-C (OR2.7, 95% CI 1.0–7.1, $P = 0.0001$), and microalbuminuria (OR7.9, 95% CI 2.0–2.0, $P = 0.0001$) were independent risk factors for promoting LEAD (Table 3).

4. Discussion

4.1. High incidence of LEAD in hospitalized elderly type 2 diabetic patients

In this study, ABI < 0.9 was used as the diagnostic standard of LEAD. The incidence rate of LEAD in hospitalized elderly patients with type 2 diabetes was 43%; mild, moderate, and severe vascular stenosis incidence was 67.7%, 27.5%, and 4.9%, respectively. In 2012, Chen Qian-lan in her community research found that the incidence of LEAD was 12.9%; mild, moderated, and severe vascular stenosis incidence was 71.4%, 27.8%, and 3.8%, respectively [18]. Compared with community research, LEAD incidence in this study is higher, and disease is severer. The possible reasons for this situation are the following. (1) All subjects in this study were elderly people (71.4 ± 7.9 vs. 58.9 ± 10.4 years). As a clear risk factor, age increased the incidence of LEAD. (2) Compared with community people, hospitalized patients had longer disease course (12.8 ± 9.3 vs. 5.52 ± 1.8 years); this factor also increased the risk of LEAD [19]. The incidence of LEAD in patients with diabetes is 20 times higher than that of the nondiabetic patients; 80% of diabetic patients have had LEAD when they were diagnosed with diabetes [20]. LEAD can lead to diabetic foot ulcers, even amputations and other serious

Table 1
Compare between clinical characteristics of LEAD group and non LAED group, mild, moderate and severe stenosis group (Mean ± SD, %).

	All patients ($n = 237$)	Non LAED group ($n = 135$)	LEAD group ($n = 102$)	t/χ^2	P	Mild stenosis group ($n = 69$)	Moderate stenosis group ($n = 28$)	Severe stenosis group ($n = 5$)	F/χ^2	P
M/F (%)	50.6/49.4	52.6/47.4	48/52	0.482	0.488	49.3/50.7	50/50	20/80	1.660	0.463
Age (year)	71.4 ± 7.9	70.1 ± 7.2	73.0 ± 8.5	2.843	0.005**	71.6 ± 8.0	75.7 ± 9.2	77.2 ± 5.8	5.186	0.007**
BMI (kg/m^2)	24.7 ± 3.7	25.1 ± 4.0	24.2 ± 3.4	−1.814	0.071	24.3 ± 3.7	24.4 ± 2.8	22.0 ± 1.7	3.810	0.025*
Hypertension (year)	10.8 ± 11.8	9.5 ± 12.1	12.4 ± 11.3	1.910	0.057	12.4 ± 11.2	12.0 ± 11.9	14.6 ± 9.8	0.307	0.736
Diabetes duration (year)	12.8 ± 9.3	11.7 ± 8.6	14.2 ± 10.0	2.096	0.037*	13.6 ± 10.4	15.6 ± 9.2	14.6 ± 10.3	0.637	0.531
peak velocity (cm/s)	27.2 ± 14.2	29.7 ± 14.4	23.8 ± 13.3	−3.243	0.001**	26.7 ± 12.7	19.1 ± 12.7	9.6 ± 6.6	14.632	0.001**
HbA1c (%)	8.1 ± 2.1	8.1 ± 2.0	8.1 ± 2.2	−0.190	0.849	8.0 ± 2.4	8.3 ± 1.9	8.0 ± 1.9	0.271	0.763
GA (%)	23.2 ± 8.8	23.1 ± 8.6	23.4 ± 9.1	0.321	0.749	23.1 ± 9.9	24.4 ± 7.3	22.2 ± 5.6	0.561	0.572
TCH (mmol/L)	4.7 ± 1.4	4.5 ± 1.3	4.9 ± 1.4	1.935	0.054	4.9 ± 1.5	1.9 ± 1.4	4.6 ± 0.2	0.351	0.704
TG (mmol/L)	2.4 ± 4.4	2.3 ± 4.3	2.5 ± 4.4	0.417	0.677	2.9 ± 5.3	1.8 ± 1.4	1.8 ± 0.5	1.439	0.241
HDL-C (mmol/L)	1.4 ± 1.0	1.3 ± 0.8	1.4 ± 1.3	0.332	0.740	1.5 ± 1.5	1.1 ± 0.3	0.9 ± 0.3	3.430	0.035*
LDL-C (mmol/L)	2.6 ± 0.9	2.5 ± 0.8	2.7 ± 0.9	1.346	0.180	2.6 ± 0.9	2.8 ± 1.0	2.7 ± 0.4	0.461	0.632
Urinary microalbumin (%nor/abnor)	54.4/45.6	60.7/39.3	46.1/53.9	5.036	0.025*	53.6/46.4	35.7/64.3	0/100	7.064	0.029*
Vibration sense (%, nor/abnor)	60.3/39.7	69.6/30.4	48.0/52.0	11.317	0.001**	52.2/47.8	42.9/57.1	20/80	2.326	0.313
Pressure sense (%, nor/abnor)	84.4/15.6	84.4/15.6	85.3/14.7	0.033	0.857	87.0/13.0	78.6/21.4	100/0	2.003	0.367
Temperature sense (%, nor/abnor)	84.8/15.2	85.9/14.1	82.4/17.6	0.563	0.453	87.0/13.0	71.4/28.6	80/20	3.292	0.193

Notes: *$P < 0.05$, **$P < 0.01$. BMI: body mass index. HbA1c: hemoglobinA1c. GA: glycated albumin. TCH: total cholesterol. TG: triglycerides. HDL-C: HDL cholesterol. LDL-C: LDL cholesterol.

Table 2
Stepwise multiple logistic regression analysis of factors for LEAD.

	B	S.E	Wals	df	Sig.	OR (95%CI)
Microalbuminuria	0.611	0.297	4.228	1	0.040*	1.8 (1.0–3.3)
Vibratory sensory neuropathy	0.788	0.297	7.033	1	0.008**	2.2 (1.2–3.9)

Notes: *$P < 0.05$, **$P < 0.01$.

Table 3
Stepwise multiple logistic regression analysis of factors for importing LEAD.

	B	S.E	Wals	df	Sig.	OR (95%CI)
BMI	−18.633	0.456	1669.266	1	0.0001**	1.4 (1.0–1.8)
Microalbuminuria	18.535	0.464	1596.124	1	0.0001**	7.9 (2.0–2.0)
HDL-C	17.173	0.738	542.131	1	0.0001**	2.7 (1.0–7.1)

Notes: *$P < 0.05$, **$P < 0.01$.

consequences. Diabetic LEAD accounts for more than 50% in non-traumatic amputations and is the main reason for high amputation and reamputation [20].

4.2. Microalbumin is a major risk factor for occurrence and development of LEAD

Besides predicting diabetic microangiopathy, microalbumin is also a predictor of macrovascular disease. It can early predict the occurrence and development of LEAD [21]. In this study, multiple logistic regression analysis showed the significant differences in urinary albumin between groups A and B (Table 2) and between groups B1, B2, and B3 (Table 3). LEAD in the normal albuminuria group accounted for 46.1%, and LEAD in microalbuminuria group accounted for 53.9% (Table 1). Microalbumin was an independent risk factor for promoting occurrence and development of LEAD in patients with diabetes, and LEAD incidence was increasing constantly along with increased urinary albumin. In 2008, a Taiwan scholar investigated 508 elderly diabetic patients. Results implied that LEAD incidence was positively correlated with urine microalbumin. The risk of LEAD occurrence in the microalbuminuria group is 2.12 times that of the normal albuminuria group [19], which is consistent with the results of this study. LEAD is closely correlated with microalbuminuria, but the mechanism is still not clear. Scholars believe that systemic vascular endothelial dysfunction is a common underlying factor of urinary albumin and LEAD. Studies confirmed that endothelial dysfunction exists not only in the renal microvasculature but also in the lower extremity arteries. Plasma protein can leak into the large vascular intima through the damaged endothelial cell, increasing the intimal thickness, leading to atherosclerosis, and eventually causing LEAD [22]. Additionally, increased endothelial permeability, enhanced oxidative stress, and inflammatory reaction after vascular endothelial cell injury are some of the other reasons for lower extremity arterial atherosclerosis [23].

4.3. Peripheral neuropathy is a main predictor of LEAD

In this study, 237 hospitalized elderly patients with type 2 diabetes were screened by ABI and sensory nerve function examination. Results showed that vibratory sensory neuropathy in the LEAD group was significantly higher than those in the non-LEAD group (52.0% vs 30.4%) (Table 1). Multiple logistic regression analysis indicated that vibratory sensory neuropathy was an independent risk factor for LEAD ($P < 0.01$) (Table 2). Vibration perception examination is a common and reliable screening method for peripheral neuropathy clinically; the sensitivity is 74.4%, specificity is 100%, and accuracy is 89.9% when combined with neuropathy symptoms [24]. Pressure sense examination is used to evaluate foot protective sensation, but the sensitivity is poor. It can only detect nerve damage that has developed above 20–30 cm. A considerable number of patients have normal pressure sense among people with abnormal vibration perception. Some scholars have pointed out that the pressure sense screen may not be suitable for assessing diabetic peripheral neuropathy and is more suitable for diabetic foot ulcer risk assessment [24]. Temperature sense examination is used to evaluate sensory function of small nerve fibers. Small nerve fiber lesions occur mainly in the early stage of diabetes. The average duration of diabetes in this research is more than 10 years; this may be the reason why no significant difference in temperature sense function was found between patients with and without LEAD. Studies have confirmed that diabetic neuropathy is associated closely with arterial intimal calcification [25]. Yang Guangran [26] proved that LEAD was positively correlated with peripheral neuropathy. The possible reason is that LEAD can directly cause decreased blood flow in nerve artery, especially the popliteal artery, posterior tibial artery, and peroneal artery, thereby resulting in poor nutrition in the peripheral nerve, eventually causing peripheral neuropathy [27]. Therefore, improving microcirculation in patients with LEAD but without neuropathy can delay the occurrence of peripheral neuropathy. In additional to neuropathy treatment, improving blood circulation can also help improve the nerve function in diabetic neuropathy patients.

LEAD is affected by many factors, including age, diabetes duration, hypertension, 2 h postprandial blood glucose, HbA1c, LDL-C, and TG [28,29]. Studies have confirmed a negative correlation between HDL and LEAD. HDL is an independent predictor of LEAD, which is consistent with this study. HDL has a function of reversing cholesterol; it carries antioxidant enzymes which can block atherosclerosis. Along with 1 mg/dl increase of HDL, risk of LEAD decreases by 3% [19]. Consistent with the research of Rhee [29], this study found a negative correlation between BMI and LEAD. BMI was an independent risk factor for LEAD. The possible reason is that the people with low body weight have a higher metabolic rate, more serious inflammatory reaction, and poorer bone antioxidant ability, which increase the risk of LEAD [30]. The degree of arterial stenosis can be evaluated by the hemodynamics. Arterial stenosis can increase the blood flow resistance, resulting in decreased systolic peak flow velocity. In this study, the peak systolic velocity was significantly different between groups A and B and between groups B1, B2, and B3. Pan Ying [20] obtained results that are consistent with those obtained in this study. ABI was positively associated with peak systolic velocity ($r = 0.58$, $P < 0.01$); low ABI leads to low peak velocity.

In conclusion, LEAD is a common lager vascular complication of diabetes that is associated with many factors. It is hard to detect LEAD at the early stage of diabetes, because of the lack of obvious symptoms. However, with the progression of the disease, LEAD patients will have low limb ischemia, intermittent claudication, ulcer, necrosis, and even possible amputation, thereby resulting in serious social economic burden and poor prognosis. Therefore, early screening and diagnosis and timely detecting LEAD patients and high-risk groups are the keys to preventing LEAD.

Conflict of interest statement

There are no conflicts of interest.

Funding

This project was funded by Shanghai Municipal Commission of Health and Family Planning, Key Developing Disciplines (2015ZB0501) and Project of Shanghai Science and Technology Commission (16411971300).

Acknowledgement

We are grateful to the all staffs in the Department of Endocrinology of Huadong Hospital affiliated to FuDan University for their support in collecting data.

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