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FULL PAPER

Curative effect and mechanism of radiofrequency ablation nucleoplasty in the treatment of cervical vertigo

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Objective: This study aims to investigate the curative effects and mechanism of radiofrequency ablation nucleoplasty in the treatment of cervical vertigo.

Methods: A total of 27 patients diagnosed with cervical vertigo from January 2012 to October 2014 received treatment of radiofrequency ablation nucleoplasty. The narrow-side vertebral artery diameters were examined by using Philips 1.5-T body dual-gradient MRI system. The haemodynamic parameters were detected by using transcranial Doppler sonography. Both of the vertebral artery diameters and haemodynamic parameters were recorded and compared before and after treatment. The curative effects in early post-operative application were evaluated according to the Nagashima standards.

Results: Radiofrequency ablation nucleoplasty was performed in a total of 59 cervical discs in 27 patients.

The average operation time was 42.7 min, and the symptoms of 92.6% patients were alleviated after radiofrequency ablation nucleoplasty post-operation application. There was no significant difference in the narrow-side vertebral artery diameters before and after treatment in both Group A ($p = 0.12$) and Group B ($p = 0.48$); however, the blood flow velocity was significantly higher than that before treatment in both Group A ($p = 0.01$) and Group B ($p = 0.03$), respectively.

Conclusion: Radiofrequency ablation nucleoplasty improves the blood flow in the narrow-side vertebral artery and illustrates the therapeutic effect on cervical vertigo in patients who have no direct compression of the vertebral artery.

Advances in knowledge: Radiofrequency intradiscal nucleoplasty can be used as a minimally invasive procedure for treating cervical vertigo.

INTRODUCTION

Cervical vertigo is a kind of vertigo or dizziness, which is always initiated by a certain neck posture and is independent of the orientation of the head. For instance, when sitting up straight, dizziness could be provoked by turning the head to the vertical axis. There is also a report that defines vertigo due to neck disorders.¹ The accurate morbidity of cervical vertigo is controversial. However, about 20–58% of patients who have closed-head injuries or whiplash suffer the symptoms of dizziness, vertigo and disequilibrium. In this respect, it is also found that driving disturbances always occur in patients with chronic whiplash-associated vertigo and account for about 73% according to Takasaki et al's report.² Cervical vertigo is worth to gain great attention due to the high litigation-related costs of whiplash injuries. Cervical vertigo caused by other reasons is much less common. The perception of

head rotation is mediated by the vestibular, proprioceptive or visual receptors. Therefore, vertigo could be provoked by the stimulation of any of these systems.

Radiofrequency intradiscal nucleoplasty (RIN) is a minimally invasive percutaneous intradiscal treatment method, which uses the patented coblation technology for ablation and coagulating the intervertebral disc. RIN is always performed by using a transmitter device named the coblation technology, which depends on the transmission of radiofrequency energy. The technology could create a low-temperature plasma field of ionized particles, which could breakdown the organic molecular bonds within the injured tissues and create small channels in the disc.³

In patients who underwent RIN, the therapy could bring some positive outcomes, including a small portion of the

coagulated nucleus pulposus, reduced intradiscal pressure and reduced pressure on the annulus fibrosus and nerve root.⁴⁻⁷ Furthermore, RIN could relieve the symptoms of patients with lumbar disc herniation.⁸ Kloth et al⁹ reported that RIN could be preferred for treating radicular pain caused by disc herniation. Kumar et al¹⁰ proved that RIN could relieve pain, treat functional disability and improve the quality of life of patients with discogenic low-back pain. Bokov et al¹¹ reported that RIN significantly decreases leg pain and brings about faster recovery in contained disc herniation patients. Mirzai et al¹² also discovered the satisfactory outcomes for disc herniations-caused leg pain, including pain reduction, functional disability, patient satisfaction and analgesia requirement.

We speculated that RIN may be also effective for treating neck and head-related diseases. Therefore, the present study aims to investigate the curative effect and mechanism of radiofrequency ablation nucleoplasty in the treatment of cervical vertigo.

METHODS AND MATERIALS

Subjects

Sympathetic cervical spondylosis patients with cervical vertigo were treated with radiofrequency ablation nucleoplasty in our hospital from January 2012 to October 2014. All patients were diagnosed by specialist consultation in the Departments of Internal Medicine, Neurology and Otorhinolaryngology and other related departments.

Exclusion criteria: (1) previous lumbar disc operation patients; (2) radiological evidence of annular tear and disc sequestration; (3) history of uncontrolled psychological disorder; (4) spinal stenosis; (5) multilevel disc herniation.

A total of 27 patients were included in this study, including 12 males and 15 females. The ages ranged from 47 to 72 years, with a mean age of 58.7 years. The condition of the cervical spine examined by using radiographic and MR manifestations

are as follows: all patients had cervical degenerative changes and various degrees of cervical disc protrusion (fibre ring was complete), including 6 cases with single-segmental lumbar disc herniation, 13 cases with double-segmental lumbar disc herniation, 5 cases with 3-segment lumbar disc herniation and 3 cases with segments lumbar disc herniation. There were 3 cases with cervical vertebra instability on imaging performance. Dynamic X imaging indicated that dynamic adjacent vertebral slip is >2 mm, $>10^\circ$ angle or curvature change or change of physiological curvature.⁶ All subjects were divided into Group A and Group B, according to the direction of rotation induced by cervical vertigo. Group A was composed of 15 cases with the neck rotation test (+) on the right side, and MR angiography (MRA) showed distorted left vertebral artery stenosis (Figure 1). Group B was composed of 12 cases with left-neck rotation test (+), and MRA showed a twisted right vertebral artery stenosis (Figure 2). With the patient's recovery to the neutral position, the symptoms disappeared in all patients with cervical vertigo. This study was approved by the ethics committee of the First People's Hospital of Shunde city. Written informed consent was obtained from each individual prior to their participation in the study.

Treatment procedures

All sympathetic cervical spondylosis patients with cervical vertigo were treated with radiofrequency ablation nucleoplasty by using the America plasma operation system produced by ArthroCare company (type Atlas; Austin, TX). All subjects were given local anesthesia, and C-arm X-ray fluoroscopy assisted us to make sure of the localization of the cervical vertebra lesion.

For the patients treated with radiofrequency ablation, the Lide LDRF-120S radiofrequency therapy instrument was used (operating frequency: 400 kHz), which is equipped with a LDRF-120S multipolar RAF electrode needle. Before radiofrequency ablation, the patients must pre-operatively fast for

Figure 1. The distortion of left vertebral artery stenosis in MRA. The white arrow illustrates the distortion.

Figure 2. The MRA twisted right vertebral artery stenosis. The white arrow illustrates the twisting.

4–6 h and take the appropriate position under B-ultrasound guidance. Then, B-ultrasound detects liver cancer position. We chose the best puncture point and mark and applied routine disinfected towel. The puncture needle with a diameter of 3 mm was inserted from the anterior lateral position (between the vascular sheath and visceral sheath) to the intervertebral puncture. The lateral fluoroscopic puncture needle was located at the midpoint of the intervertebral space after pulling out the needle core, then inserting a special plasma cutter head cervical vertebra, monitoring the position of the needle-tip ring-electrode remote plasma using fluoroscopic and stepping on the coagulation pedal for half second. If irritation symptoms occurred, the cutter head was replaced. If the patient was well, we stepped on the ablation of the pedal for 15 s. At the same time, we rotated the plasma cutter head for 180° (Figures 3 and 4). After ablation, when the plasma cutter head sign out about 2–3 mm, we repeated the above steps again two times. Brake hard neck was used for supporting neck for 1 week. All patients were not using hormone and vasodilator before and after operation.

Figure 3. Intraoperative anteroposterior fluoroscopy. In the intraoperative anteroposterior fluoroscopy, in addition to obtaining an accurate reduction, combining the osteological details with the corresponding intraoperative fluoroscopic imaging is necessary to safely perform percutaneous fixation. The inlet and outlet fluoroscopic views are utilized to safely place iliosacral screws. An intraoperative lateral fluoroscopic view can be extremely helpful by providing a third dimension that helps verify the osteology seen in the inlet and outlet views.

Assessment of the effectiveness of the procedure

Philips 1.5-T body dual-gradient MRI system was used to measure and record the left vertebral artery diameter in Group A and the right vertebral artery diameter in Group B, before and after treatment at the chin-tip level (approximately at flat 3–4 cervical transverse foramen level). Each side of the vertebral artery was measured three times by using the picture archiving and communication system software according to the instructions of the manufacturer, and the average value was obtained.

Ultrasound MT-1000-type America MET transcranial colour Doppler was used to investigate the vertebral artery intracranial segment of the left side of Group A and the right side of Group B. Researchers used the protractor to measure the top angle, indicating needle rotation angle and the direction of the cervical spine. We measured the rotation angle and the ipsilateral vertebral artery blood flow when the neck rotation induced by cervical vertigo occurred before treatment. We measured vertebral artery blood flow when the cervical rotated to the side of the lesion at the same angle. In the occipital window sampling, all patients were checked three times. We also recorded the haemodynamic parameters in the ipsilateral vertebral artery of the

Figure 4. Intraoperative lateral fluoroscopy. In the intraoperative lateral fluoroscopy, in addition to obtaining an accurate reduction, combining the osteological details with the corresponding intraoperative fluoroscopic imaging is necessary to safely perform percutaneous fixation. The inlet and outlet fluoroscopic views are utilized to safely place iliosacral screws. An intraoperative lateral fluoroscopic view can be extremely helpful by providing a third dimension that helps verify the osteology seen in the inlet and outlet views.

two groups before and after surgery, including the peak systolic velocity (V_p), mean blood flow velocity (V_m) and end diastolic velocity (V_d), and reflect the vascular compliance and elasticity of blood vessel pulsatility index (PI), the resistance index of vasomotor and resistance status (RI).

The early effect on post-operative application was defined based on the Nagashima standards.⁷ When symptoms disappeared completely, the treatment was “excellent”; when most of the symptoms relieved but some residual symptoms were present, the treatment was “good”; and when symptoms remained the same or worsened, the treatment was “poor”.

Statistical analysis

The data analysis in this study was performed by using SPSS® v. 17.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). All of the data were expressed as mean $\pm$ standard deviation. The Student's *t*-test was used for comparison between the two groups. The *p*-values <0.05 were considered statistically significant.

RESULTS

A total of 27 patients were included in the study, and 59 cervical intervertebral discs with pathological changes were treated by using radiofrequency ablation nucleoplasty. The operation time ranged from 25 to 77 min, with the average operation time of 42.7 min. No serious complications occurred in large vessels, oesophageal, cervical nerve root. The curative effect was excellent in 14 cases, good in 11 cases and poor in 2 cases, and the excellent and good rate achieves to 92.6%.

Ipsilateral vertebral artery diameter was measured in two groups, before and after operation. In Group A (vertebral artery stenosis), there was no significant difference before operation (3.3 ± 0.57 mm) and after operation (3.6 ± 0.79 mm) ($p = 0.12$). In Group B (the right vertebral artery stenosis), there was no significant difference before operation (2.9 ± 0.42 mm) and after operation (3.0 ± 0.65 mm) ($p = 0.48$).

Table 1 shows the cervical rotatory angle in the two groups for subjects with positive result in the neck rotation test, and we found no significant difference between Group A and Group B. We also compared the lesions of the lateral vertebral artery diameter changes and vertebral artery haemodynamic parameters before and after operation between the two groups (Table 2).

Table 1. The cervical rotatory angle in two groups of neck rotation test (+)

	Angle of rotation			Total (N)
	$<30^\circ$	$30-60^\circ$	$>60^\circ$	
Group A (n)	2	9	4	15
Group B (n)	2	7	3	12
Total (N)	4	16	7	27

There were differences for the V_p , V_m and V_d before operation and after operation. In Group A, the V_p (32.26 ± 7.35), V_m (25.34 ± 4.79) and V_d (12.1 ± 4.3) before operation were lower significantly than the V_p (49.33 ± 6.76), V_m (39.42 ± 7.23) and V_d (16.2 ± 3.29) after operation (Table 2, $p = 0.003$, 0.01 and 0.03 , respectively). In Group B, the V_p (31.43 ± 6.64), V_m (26.18 ± 5.66) and V_d (12.8 ± 5.15) before operation were significantly less than the V_p (47.25 ± 8.11), V_m (37.96 ± 6.78) and V_d (15.9 ± 4.10) after operation (Table 2, $p = 0.009$, 0.03 and 0.03 , respectively). However, we did not find any difference before operation and after operation in both Group A and Group B in PI and RI (Table 2).

DISCUSSION

In this study, we proved that the symptoms of 92.6% of the patients were alleviated after radiofrequency ablation nucleoplasty post operation. There was no significant difference in narrow-side vertebral artery diameters before and after treatment both in Group A and Group B. The blood flow velocity was higher after treatment than before treatment in both Group A and Group B.

Previous studies^{6,7,13} have reported that patients could be diagnosed for cervical spondylosis of the vertebral artery when following a few conditions. Therefore, this study was divided into Group A and Group B. Group A shows a distorted left vertebral artery stenosis (Figure 1) and Group B shows a twisted right vertebral artery stenosis (Figure 2). Although the direction of rotation is different in cervical vertigo, there were no differences for the ipsilateral vertebral artery diameter between the two groups, as well as between the groups before operation and after operation. This result was consistent with previous studies^{14,15} that showed there was no correlation between the severity of cervical vertigo and the direction of neck rotation.

In the clinical practice, it is infrequent for vertebral artery type of cervical spondylosis due to the lateral uncovertebral joint hyperplasia and compression of the vertebral artery in cervical vertigo. We also found no evidence of vertebral artery compression in vertebral artery CT angiography or MRA of patients. It is more common for cervical vertigo (sympathetic cervical spondylosis) to occur in clinical practice¹⁶ because of degeneration of cervical spine instability and lumbar disc herniation. Among the patients involved in this, we also have not discovered the vertebral artery compression in vertebral artery CT angiography and MRA of patients. In clinical practice, the internal pressure of intervertebral disc results in abnormal sympathetic activation and vertebral artery smooth muscle contraction, both of which cause clinical symptoms of vertebrobasilar insufficiency. In this study, we found that there were no significant differences for the cervical rotatory angle between Group A and Group B, as well as between the groups before operation and after operation. Meanwhile, the $30-60^\circ$ of the cervical rotatory angle dominants the majority in all of the cervical vertigo patients in Group A (9/15) and Group B (7/12). All of the patients (23 patients) with the cervical rotatory angle $>30^\circ$ underwent the symptom of dizziness. These results suggest that the lateral vertebral artery blood flow of the lesion side was insufficient for compensation and can provide a reference for

Table 2. Ipsilateral vertebral artery parameters were measured in two groups before and after operation

	Group A		<i>p</i> -values	Group B		<i>p</i> -values
	Before operation	After operation		Before operation	After operation	
V_p (cm s ⁻¹)	32.26 ± 7.35	49.33 ± 6.76	0.003 ^a	31.43 ± 6.64	47.25 ± 8.11	0.009 ^a
V_m (cm s ⁻¹)	25.34 ± 4.79	39.42 ± 7.23	0.01 ^a	26.18 ± 5.66	37.96 ± 6.78	0.03 ^a
V_d (cm s ⁻¹)	12.1 ± 4.30	16.2 ± 3.29	0.02 ^a	12.8 ± 5.15	15.9 ± 4.10	0.03 ^a
PI	1.25 ± 0.11	1.22 ± 0.14	0.17	1.24 ± 0.28	1.22 ± 0.09	0.58
RI	0.66 ± 0.06	0.59 ± 0.18	0.09	0.68 ± 0.13	0.64 ± 0.25	0.16

PI, pulsatility index; RI, resistance index; V_p , peak systolic velocity; V_m , mean blood flow velocity; V_d , end diastolic velocity.

the clinical diagnosis of sympathetic cervical spondylosis. However, the direction of neck rotation and the cervical rotatory angle are useful information for the diagnosis of vertigo induced by neck rotation.¹⁷

In this study, we found that pre-operative symptoms of 25 cases (92.6%) with cervical vertigo were alleviated after radiofrequency ablation nucleoplasty treatment, which suggests that the curative effect of radiofrequency ablation nucleoplasty on sympathetic cervical spondylosis was effective. This result is consistent with previous studies.^{18,19} According to our results and the literature reviews, we speculated that the mechanism of cervical vertigo may be as follows: radiofrequency ablation can be decomposed into nucleus pulposus, which leads to the reduction of intradiscal pressure, stimulation and the oppression of the peripheral sympathetic nervous system, vascular smooth muscle relaxation and the ease of vertebrobasilar artery insufficiency.²⁰ Radiofrequency ablation nucleoplasty mainly plays the role of therapy through strong RF field (100 kHz) of the electrolyte into the plasma state, forming a plasma layer thickness of about 10 m in front of the ablation electrode. Finally, undergoing the radiofrequency ablation nucleoplasty treatment, the molecular units of the target cells collapsed and formed the elements and low molecular weight gases (oxygen, nitrogen, hydrogen and carbon dioxide).²¹ Nardi et al⁴ reported that the symptoms of 80% of patients got complete remission in the follow-up after radiofrequency ablation nucleoplasty operation. Some studies^{22,23} have documented a perfect effect on radiofrequency ablation nucleoplasty treatment for cervical disc herniation.

Interestingly, we found for the first time that V_p , V_m and V_d were significantly different before and after operation both in Group A and Group B (Table 2). However, we have not found

a significant difference in PI and RI before and after operation in Group A and Group B (Table 2). Liu et al²⁴ also proved that radiofrequency ablation could also obviously change V_p , V_m and V_d of the cervical vertigo patients. Therefore, we speculated that the intradiscal pressure decreased and sympathetic nerve irritation reduced after radiofrequency ablation. Moreover, the radiofrequency ablation also triggers a certain degree of vascular smooth muscle relaxation, which leads to the increasing of blood flow velocity in lesions of the lateral vertebral artery. However, PI and RI were mainly affected by the vascular intimal thickening and the atherosclerotic plaque.²⁵

Although this study received the above interesting and novel results, there are also a few limitations. Firstly, the amount of sample is limited, and we would involve more samples in the future study. Secondly, the specific mechanism of cervical vertigo has not been fully clarified. Thirdly, the application of radiofrequency ablation nucleoplasty was not compared with other methods for cervical vertigo in this study.

In conclusion, percutaneous radiofrequency nucleoplasty could reduce intradiscal pressure and alleviate the stimulation of degeneration of cervical vertebra instability for peripheral sympathetic nervous system. Then, the radiofrequency nucleoplasty could relax the vascular smooth muscle and increase the blood flow of the vertebral artery. Radiofrequency nucleoplasty was a good therapeutic method for vertebral artery cervical vertigo of non-direct compression.

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REFERENCES

- Ryan GM, Cope S. Cervical vertigo. *Lancet* 1955; **31**: 1355–8. doi: [https://doi.org/10.1016/S0140-6736\(55\)93159-7](https://doi.org/10.1016/S0140-6736(55)93159-7)
- Takasaki H, Johnston V, Treleaven J, Pereira M, Jull G. Driving with a chronic whiplash-associated disorder: a review of patients' perspectives. *Arch Phys Med Rehabil* 2011; **92**: 106–10. doi: <https://doi.org/10.1016/j.apmr.2010.10.008>
- Cheng B, Zhang Z, Pei Z. The evaluation of the application effect about resection of tongue cyst by low-temperature plasma radiofrequency ablation system. [In Chinese.] *Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi* 2015; **29**: 561–3.
- Nardi PV, Cabezas D, Cesaroni A. Percutaneous cervical nucleoplasty using coblation technology. Clinical results in fifty

- consecutive cases. *Acta Neurochir Suppl* 2005; **92**: 73–8. doi: https://doi.org/10.1007/3-211-27458-8_16
5. Lee D, Loh E, Kueh C, Poi J, Francis T, Koh K, et al. Radiofrequency-induced intradiscal nucleoplasty chronic low back pain secondary to lumbar disc herniation. *Malays Orthop J* 2013; **7**: 18–20. doi: <https://doi.org/10.5704/MOJ.1307.009>
 6. Hou S. *Spinal surgery [M]*. Beijing, China: People's Medical Publishing House; 2005. pp. 635–7.
 7. He J, Fan D, Sun Y. Cervical vertigo. *Chin J Pract Int Med* 2011; **31**: 414–5.
 8. Wu S, Li X, Lin C, Zeng W, Ma C. CT-guided nucleoplasty with radiofrequency energy for the treatment of lumbar disk herniation. *J Spinal Disord Tech* 2015; **28**: E9–16. doi: <https://doi.org/10.1097/BSD.0000000000000132>
 9. Kloth DS, Fenton DS, Andersson GB, Block JE. Intradiscal electrothermal therapy (IDET) for the treatment of discogenic low back pain: patient selection and indications for use. *Pain Physician* 2008; **11**: 659–68.
 10. Kumar NS, Shah SM, Tan BW, Juned S, Yao K. Discogenic axial back pain: is there a role for nucleoplasty? *Asian Spine J* 2013; **7**: 314–21. doi: <https://doi.org/10.4184/asj.2013.7.4.314>
 11. Bokov A, Skorodumov A, Isrelov A, Stupak Y, Kukarin A. Differential treatment of nerve root compression pain caused by lumbar disc herniation applying nucleoplasty. *Pain Physician* 2010; **13**: 469–80.
 12. Mirzai H, Tekin I, Yaman O, Bursali A. The results of nucleoplasty in patients with lumbar herniated disc: a prospective clinical study of 52 consecutive patients. *Spine J* 2007; **7**: 88–92. doi: <https://doi.org/10.1016/j.spinee.2006.02.033>
 13. Han W, Ouyang J, Sheng W. The MRA images in the cervical spondylosis of the vertebral artery insufficiency and its clinical significance. *Chin J Surg* 2001; **8**: 21–4.
 14. Shan X, Peng X, Wang E. Efficacy of computer-controlled and modified roll maneuver for treatment of geotropic lateral canal benign paroxysmal positional vertigo. *Otol Neurotol* 2015; **36**: 1412–6. doi: <https://doi.org/10.1097/MAO.0000000000000813>
 15. Demirtas H, Kayan M, Koyuncuoğlu HR, Çelik AO, Kara M, Şengeze N. Eagle syndrome causing vascular compression with cervical rotation: case report. *Pol J Radiol* 2016; **81**: 277–80.
 16. Yu Z, Liu Z, Dang G. Effect of cervical instability in sympathetic cervical spondylosis. *Chin J Surg* 2002; **40**: 881–3.
 17. Kokubo Y, Kayama T, Ikeda S. Two cases of severe vertigo occasioned by neck rotation and its correlation with the direction of vertebral artery at its origin. [In Japanese.] *No Shinkei Geka* 2003; **31**: 781–6.
 18. Zakirov AA, Dreval' ON, Chagava DA, Rynkov IP, Kuznetsov AV. Treatment of spondyloarthrosis and lumbar discopathy by combined minimally invasive techniques. [In Russian.] *Zh Vopr Neirokhir Im N N Burdenko* 2012; **76**: 17–22.
 19. Nezer D, Hermoni D. Percutaneous discectomy and intradiscal radiofrequency thermocoagulation for low back pain: evaluation according to the best available evidence. [In Hebrew.] *Harefuah* 2007; **146**: 747–50.
 20. Yang W, Cui M, Lee J, Gong W, Wang S, Fu J, et al. Heat shock protein inhibitor, quercetin, as a novel adjuvant agent to improve radiofrequency ablation-induced tumor destruction and its molecular mechanism. *Chin J Cancer Res* 2016; **28**: 1000–9604. doi: <https://doi.org/10.21147/j.issn.1000-9604.2016.05.04>
 21. Zhang RY, Zhang Y. The low-temperature plasma ablation in the application of spinal surgery. *Chin J Surg* 2007; **45**: 1148–9.
 22. Li J, Xie Q, Zhao H. Percutaneous radiofrequency nucleoplasty in the treatment of cervical disc herniation. *Chin J Spine Spinal Cord* 2007; **17**: 394–6.
 23. Wang X, Hou S, Wu W. Clinical report of nucleoplasty for treating patients with cervical and lumbar disc herniation. *Chin J Spine Spinal Cord* 2005; **15**: 334–6.
 24. Liu S, Li L, Yao K, Li W, Wang N, Cui L, et al. Application of vertebral artery ultrasonography in enlistment-age male student pilots. *Ultrasound Med Biol* 2014; **40**: 2064–8. doi: <https://doi.org/10.1016/j.ultrasmedbio.2014.04.011>
 25. Heffernan KS, Patvardhan EA, Kapur NK, Karas RH, Kuvvin JT. Peripheral augmentation index as biomarker of vascular aging: an invasive hemodynamics approach. *Eur J Appl Physiol* 2012; **112**: 2871–9. doi: <https://doi.org/10.1007/s00421-011-2255-y>