Quantitative Analysis of Fluid Velocity and Signal Loss of the TOF-MRA in a 3.0T MR System: Using the Flow Rate Control Phantom

Sang-Hoon Back,[1] Jin-Heon Jeong,[1] Ye-Eun Lee,[1] Min-Young Gwak,[1] Jun Yoon,[1] Dabin Jung,[2] Hyun-Sik Oh,[2,3] Yeong-Cheol Heo[1,2,*]

[1]Department of Radiological Sceience, Eulji University
[2]Department of Radiological Science, Graduate school Eulji University
[3]Department of Diagnostic Radiology, Samsung Medical Center

Received: November 14, 2020. Revised: December 30, 2020. Accepted: December 31, 2020

ABSTRACT

The purpose of this study was to quantitatively correlate the change of flow velocity and signal voiding in TOF-MRA. We made our phantom to control the flow velocity, and changed the flow velocity in 16 steps from 8.0 to 127.3 mc/s. The TOF-MRA test was performed using a 3.0T MRI system and the signal intensity was measured by classifying the signal voiding length and image into the In flow, Mid flow, and Out flow. The length of signal voiding was the longest when the flow velocity was 127.3 cm/s and the signal intensity decreased with increasing flow velocity($p<0.05$). In flow(-.547) and Mid flow(-.643) were negatively correlated with flow velocitys($p<0.05$). In conclusion, it was confirmed that the increase in flow velocity was a major factor causing signal voiding in TOF-MRA. In the future, this study will provide basic data when studying sequences and parameters to reduce signal voiding in models with a high flow velocity.

Keywords: TOF-MRA, Flow rate control phantom, Flow phantom, Signal void, perfusion phantom

I. INTRODUCTION

According to the Statistics Korea in 2018, cerebrovascular disease was the second highest cause of death in South Korea after cancer[1]. The causes of cerebrovascular diseases are classified into sclerosis and hemorrhagic factors, which are caused by narrowing or blockage of blood vessels[2,3]. Once a cerebrovascular disease occurs, the patients' neurological symptoms make it difficult for them to lead their lives and the social cost increases, such as increase in the pain of family members to support the patient[4]. Therefore, prevention is the best method for cerebrovascular disease, and the tests used for preventive diagnosis are CT, Conventional Angiography, MRI, and MRA. Here, since CT and conventional angiography uses X-rays, there may be a problem with radiation exposure, and since a contrast agent is required for vascular imaging, there are problems with side effects of contrast agents[5,6,7]. In particular, contrast agents can cause minor side effects such as itching and hives to serious ones such as cardiac arrest, and according to a report by Korea Consumer Agency, there were 7 cases of deaths from side effects of contrast agents in South Korea between 2014 and 2016, so careful administration is required[8]. However, the vascular imaging of the MRI tests uses radio frequency, so it can be free from exposures[9]. In addition, the Time of Flight(TOF) MRA, which enables vascular imaging without contrast agent using

* Corresponding Author: Yeong-Cheol Heo E-mail: eehrrn@hanmail.net Tel: +82-31-740-7134
Address: Department of Radiological science, college of health science, Eulji University

the hemodynamic physiological mechanism of the human body, is safe from contrast agents[10,11]. TOF-MRA makes a difference in contrast between blood vessels and surrounding tissues using the inflow effect of arteries and saturation of the surrounding tissues and reconstructs the image with Maximum Intensity Projection(MIP)[12]. However, several studies have reported the loss of vascular signal of TOF-MRA, and the signal loss occurs due to various complex problems[13,14]. However, studies that analyzed the signal change pattern of TOF-MRA in hypertensive patients, a major cause of cerebrovascular disease, are insufficient compared to its necessity. An increase in blood pressure means that the blood flow rate increases in the same lumen and that a phantom model that can reflect various blood flow rates is needed. Therefore, in this study, a phantom model made of nonmagnetic material that can control the flow rate of a conduit through pressure control was manufactured to quantitively analyze the TOF-MRA signal pattern according to various flow rates.

II. MATERIALS AND METHODS

1. Manufacturing of the Phantom

For the phantom body, a cylindrical container made of polyethylene terephthalate with a diameter of 70 mm and a height of 230 mm was used. For the vascular model, a tube that is 2mm in diameter and 3.14 mm^2 made of polyethylene resin penetrated the phantom body through the center of both bottom surfaces. At one end of the vascular model tube, a pressure line was connected to the auto injector, and on the other end, the outlet was made by extending the tube, realizing a vascular model through which blood can flow. In order to create the environment similar to blood vessels, H_2O, a tissue equivalent material, was filled inside the phantom body. Holes were made on the side of the phantom body to prevent susceptibility that may be caused by the generation of air bubbles, and using a 1cc syringe, the air bubble was removed from the point where the air bubbles occurred upon sealing it [Fig. 1].

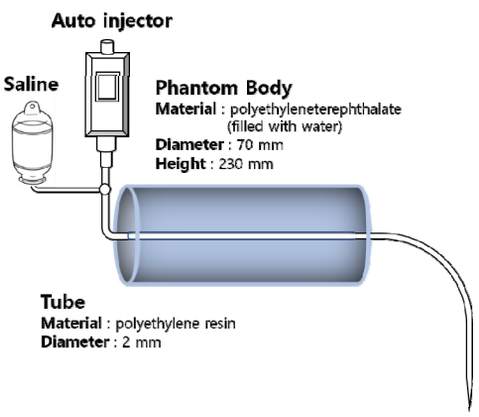

Fig. 1. Flow Phantom is an auto injector with a saline connected to it for quantitative measurement.

Auto injector was used to control the amount of fluid injected to the completed phantom per unit time, and the velocity of the fluid flowing in the conduit was controlled. The fluid velocity flowing through the conduit can be expressed as Equation (1), because the amount of fluid can be expressed as the amount of volume flowing per unit time.

$$V = Q/A \quad (1)$$

V : Flow velocity(m/sec)
Q : Volumetric flow rate//Quantity of flow(m^3/sec)
A : Conduit area(m^2)

For the fluid, physiological saline, which has negligible viscous effect and has only a small difference in viscosity from blood, was used. When calculating the fluid velocity, the friction in the tube was not taken into account. The pressure loss was neglected by placing the tube horizontally to eliminate the effect of gravity as well as the change in the average flow velocity. The fluid was kept in laminar flow with Reynolds number <2100.

2. Methods

In this study, 3.0 Tesla whole-body MRI (Achieva TX, Philips, Netherlands) was used, and the pulse

sequence used for TOF-MRA was 3D fast field echo. The parameter was TR : 20 ms, TE : 3.5 ms, Matrix : 400 × 200, Voxel : 0.45 × 0.9 × 0.5 mm^3 , NEX : 1, Slice : 30, Chunk : 1, Scan time : 22.4 s, Flip angle : 20° , Phase encoding direction : R - L, and FOV : 180 (AP) × 180 (RL) × 15 (FH) mm^3. The phantom was placed on the 32-channel SENSE head coil, and the injection site was connected with the auto injector, and the scanning was done at the center of the phantom. Fluid was injected into the phantom with an auto injector at a constant speed, and the amount of fluid injected was 0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.2, 3.5, 3.7, and 4.0 m^3/sec.

At this time, the flow velocity through the conduit was calculated as 8.0, 15.9, 23.9, 31.8, 39.8, 47.6, 55.7, 63.7, 71.6, 79.6, 87.5, 95.5, 101.9, 111.4, 117.8, and 127.3 cm/sec by substituting in Equation (1). [Table. 1].

Table 1. Flow velocity in the tube

QF (ml/s)	0.25	0.5	0.75	1	1.25	1.75	2	2.25	2.5	2.75	3	3.2	3.5	3.7	4
FV (cm/s)	8.0	15.9	23.9	31.8	39.8	47.8	56.7	63.7	71.6	79.6	87.5	95.5	101.9	111.4	117.8

QF : Quantity of Flow, FV : Flow Velocity

3. Data Analysis

Signal intensity of the image obtained after examination was analyzed using Image J (v.1.52a Java 1.8.0_112(64-bit)), and voiding length at which signal loss occurs was measured in 4 steps. The whole part of the blood flow was set as ROI, and the average value of the signal intensity was derived through the histogram of ROI. Then, a signal intensity value that was 20% reduced from the average value was calculated, and after setting a plot profile of ROI, the length of the previously calculated point of 20% reduction was measured [Fig. 2].

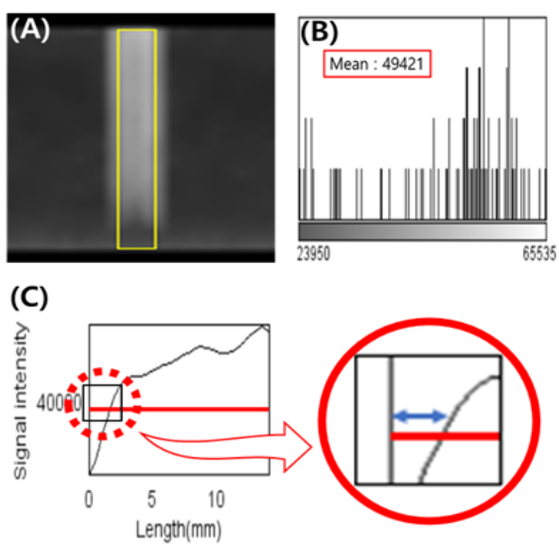

Fig. 2. ROI setting (A) Mean in histogram (B) 20% reduction point of Mean (C) and Length measurement(Arrow).

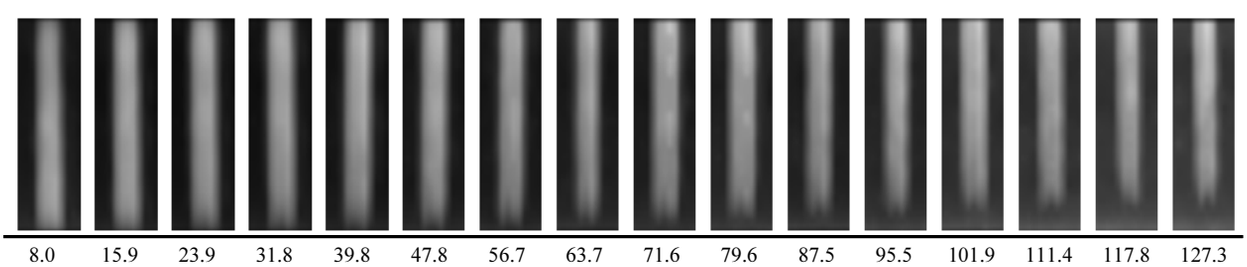

Fig. 3. Signal Loss Length in Experimental Images According to Flow Velocity(cm/s).

In order to obtain the signal intensity value of the blood flowing regions, the area was divided into three sections: In flow section where the blood flows in, mid flow section in the middle, and out flow section where the blood flows out. Each part divided the same ROI into a total of 90 sections, where ROIs numbered 1 to 30 were set as Out flow, those from 31 to 60 were set as Mid flow, and those from 61 to 90 as in-flow. A total of 4,320 data were obtained by measuring three repetitive tests for 16 different speeds.

4. Statistical Analysis

SPSS(18.0v, IBM, USA) was used for statistical processing. The Kruskal wallis test was used to compare the average value of the voiding length for each flow rate change. ANOVA test was used to analyze the average of the signal intensity in the in-flow, mid flow, and out flow sections, and Dunnett's test was used for post-test. Pearson's correlation coefficient was used to confirm whether the change in signal intensity was related to the flow velocity, and statistical significance was determined when the p value was less than 0.05.

III. RESULT

The imaging test results according to the parameters and changes in blood flow velocity are shown in [Fig. 3].

1. Voiding Length according to the blood flow velocity

The voiding length was the shortest at 8.0 cm/sec with 0.16 ± 0.08 mm and longest at 127.3 cm/sec with 2.70 ± 0.07 mm ($p < 0.05$).

Table 2. RoI's signal intensity and signal voiding length according to flow velocity with TOF-MRA

Flow velocity (cm/s)	Voiding Length (mm)	In flow	Mid flow	Out flow
FV.1 (8.0 cm/s)	0.16 ± 0.08	58.4 ± 6.4	59.9 ± 2.3	54.0 ± 4.6
FV.2 (15.9 cm/s)	0.68 ± 0.05	52.7 ± 7.9	59.6 ± 1.9	60.0 ± 3.6
FV.3 (23.9 cm/s)	0.96 ± 0.08	49.3 ± 8.5	58.9 ± 2.1	60.2 ± 2.9
FV.4 (33.8 cm/s)	1.17 ± 0.15	47.2 ± 9.0	58.3 ± 2.3	60.7 ± 2.7
FV.5 (39.8 cm/s)	1.47 ± 0.04	42.4 ± 9.1	54.4 ± 3.3	59.0 ± 3.4
FV.6 (47.8 cm/s)	1.49 ± 0.03	42.8 ± 9.7	55.4 ± 2.8	60.4 ± 2.9
FV.7 (55.7 cm/s)	1.66 ± 0.06	39.1 ± 9.4	52.3 ± 4.5	57.1 ± 4.5
FV.8 (63.7 cm/s)	1.71 ± 0.05	39.2 ± 9.7	52.1 ± 4.4	57.5 ± 5.3
FV.9 (71.6 cm/s)	1.80 ± 0.08	36.7 ± 9.7*	49.5 ± 2.8*	55.2 ± 4.5*
FV.10 (79.6 cm/s)	2.06 ± 0.13	35.8 ± 9.5*	49.5 ± 2.8*	55.8 ± 4.3*
FV.11 (87.5 cm/s)	2.19 ± 0.13	35.7 ± 9.7*	49.6 ± 3.8*	56.3 ± 5.1
FV.12 (95.5 cm/s)	2.22 ± 0.07	34.9 ± 9.2*	49.2 ± 4.0*	55.3 ± 5.2*
FV.13 (101.9 cm/s)	2.53 ± 0.10	35.1 ± 8.9	51.3 ± 4.0	57.1 ± 3.8
FV.14 (111.4 cm/s)	2.50 ± 0.11	36.5 ± 8.8	52.2 ± 3.2	58.2 ± 3.4
FV.15 (117.8 cm/s)	2.54 ± 0.17	36.9 ± 8.2	51.5 ± 3.3	57.3 ± 3.4
FV.16 (127.3 cm/s)	2.70 ± 0.07	35.0 ± 7.6	49.4 ± 4.0	54.5 ± 5.1
P1, P1*	.000	.000_p1*	.000_p1*	.000_p1*
P2	N/A	-.547	-.643	-.192

FV : Flow Velocity, Signal intensity result : actual signal intensity/1000, P1 kruskal-walistest, P1* ANOVA test, *post-hoc test(Dunnett), P2 pearson's correlation test,

2. Signal Intensity for each ROI

In the in-flow region, signal intensity was the highest at 8.0 cm/sec with 58.4 ± 6.4 and lowest at 95.5 cm/sec with 34.9 ± 9.2, and there was a negative correlation in which the signal intensity decreased as the blood flow velocity increased ($p < 0.05$). In Mid flow, signal intensity was the highest at 8.0 cm/sec with 59.9 ± 2.3 and lowest at 95.5 cm/sec with 49.2 ± 4.0. In the out-flow region, signal intensity was the highest at 31.8 cm/sec with 60.7 ± 2.7 and lowest at 8.0 cm/sec with 54.0 ± 4.6 ($p < 0.05$)[Table. 2].

IV. DISCUSSION

Time of Flight(TOF) MRA uses a magnetic field so there is no radiation exposure, and the test is safe from problems with contrast agents, as vascular imaging is possible without them by looking at the difference in contrast between the artery and the surrounding tissues using the inflow effect of the artery and saturation of the nearby tissues[15,16,17]. However, since TOF-MRA uses hematological information, signal loss due to various factors is inevitable. Previous studies reported that signal loss occurs due to changes in blood flow characteristics such as blood turbulence, circulatory arrest, and aneurysm, but analysis of individual factors related to signal loss was insufficient[18,19]. In order to analyze the correlation with signal loss by changing the controllable blood flow velocity among the various factors of TOF-MRA, we made a nonmagnetic phantom that can control the fluid velocity and measured it with various fluid injection rates. As a result, as the fluid velocity increased, the signal loss was observed in the in-flow and the mid flow regions, which showed that as the fluid velocity increased, there was a loss of signal at the in-flow and mid flow regions, and the images changed due to an increase in blood velocity. Signal intensity decreased from the in-flow to the mid flow regions as the blood flow velocity increased, showing a negative correlation. There was a positive correlation with the increase in velocity ($p<0.5$), and when the blood flow rate was 127.3 cm/s, there was a signal loss of 2.70 ± 0.07mm at the in-flow.

The known causes of signal loss are turbulence due to vascular stenosis, aneurysm which is a vascular disease, and increase in blood velocity due to pressure increase caused by vascular stenosis[20]. There is a study that reported that plaque in blood vessels caused by cholesterol causes arteriosclerosis due to calcification of blood vessels, which narrows the inner diameter of blood vessels, resulting in improper circulation of blood and blood turbulence, leading to blood stasis and signal loss[21]. In addition, OSHINSKI[22] found that a change in signal intensity occurs due to blood turbulence. However, there are only reports that signals cannot be received due to turbulence caused by changes in the inner diameter of blood vessels and no analysis of individual factors.

According to Bosmans[23], Cirillo[24] signal loss was reported in blood vessels where aneurysm occurred. Aneurysms are caused by swelling due to pressure applied to a blood vessel in which a stenosis occurred, and even if RF pulses are applied, the blood cannot flow so the signal gets lost. Signal loss due to aneurysm has a similar effect to blood turbulence due to the slowing of blood flow, and likewise, there are only findings that signal loss occurs due to blood stasis and no analysis of blood velocity and signal loss

A study shows that the blood velocity increases due to an increase in pressure caused by stenosis[25,26]. Based on the fact that the fluid velocity increases when the amount of fluid is constant and the inner diameter decreases, the fluid velocity in the blood vessels increases. However, there is no analysis of individual factors for the correlation between increase in velocity and signal loss.

As the reason for the lack of analysis was considered to be insufficient phantoms to measure this, we created a phantom for the study to analyze the correlation between the increase in fluid velocity and

signal loss. As a result, signal intensity decreased as the fluid velocity increased, showing a negative correlation, and as the fluid velocity increased, signals did not appear in the in-flow and the mid flow regions.

The injection rate of MRI contrast agents mainly used in clinical practice is 2-4 ml/sec, which is within the range of 0.5-4 ml/sec set in this study. In the TOF-MRA test, injection rate at 2 ml/sec to the in-flow region led to 80 mm signal loss, and that at 4 ml/sec to the mid flow region led to 127mm signal loss.

The limitation of this study was that it did not apply various pulse sequences, and it did not suggest a method to inhibit the increase in blood velocity using the parameter. Since the study was only on laminar blood flow by examining the increase in velocity due to pressure change, future study on the signal loss due to decrease in velocity caused by blood turbulence seems necessary. Nevertheless, this study is significant in that the correlation between blood flow velocity and signal loss was analyzed from the signal loss of TOF-MRA and that the possibility of signal loss between the in-flow and the mid flow regions when the fluid velocity increases was observed.

V. CONCLUSION

This study presented a phantom model that can measure and control the blood velocity and confirmed that the increase in blood flow velocity was a major factor in signal loss of TOF-MRA. This study will provide basic data in a future study that changes the sequence and parameter of TOF-MRA and inhibits signal loss in the area where the blood velocity is fast.

ACKNOWLEDGEMENTS

This research was supported by 2020 eulji university, University Innovation Support Project grant funded.

References

[1] KOSIS, "Cause-of-death statistics in 2018 in the Republic of Korea", Journal of the Korean Medical Association, Vol. 61, No. 9, pp. 573-584, 2018.

[2] F. Levi, F. Lucchini, E. Negri, C. La Vecchia, "Trends in mortality from cardiovascular and cerebrovascular diseases in Europe and other areas of the world", Heart, Vol. 88, No. 2, pp. 119-124, 2002. https://doi.org/10.1136/heart.88.2.119

[3] Carmine Izzo, Albino Carrizzo, Antonia Alfano, Nicola Virtuoso, Mario Capunzo, Mariaconsiglia Calabrese, Eros De Simone, Sebastiano Sciarretta, Giacomo Frati, Marco Oliveti, Antonio Damato, Mariateresa Ambrosio, Francesco De Caro, Paolo Remondelli, Carmine Vecchione, "The impact of aging on cardio and cerebrovascular diseases", International Journal of molecular sciences, Vol. 19, No. 2, pp. 481, 2018. http://dx.doi.org/10.3390/ijms19020481

[4] R. Luengo-Fernández, J. Leal, A. Gray, S. Petersen, M. Rayner "Cost of cardiovascular diseases in the United Kingdom", Heart, Vol. 92, No. 10, pp. 1384-1389, 2006. http://dx.doi.org/10.1136/hrt.2005.072173

[5] D. A. Katz, M. P. Marks, S. A. Napel, P. M. Bracci, S. L. Roberts, "Circle of Willispp. evaluation with spiral CT angiography, MR angiography, and conventional angiography", Radiology, Vol. 195, No. 2, pp. 445-449, 1995. http://dx.doi.org/10.1148/radiology.195.2.7724764

[6] Klaus D. Hagspiel, Lucia Flors, Michael Hanley, Patrick T. Norton, "Computed tomography angiography and magnetic resonance angiography imaging of the mesenteric vasculature", Techniques in Vascular and Interventional Radiology, Vol. 18, No. 1, pp. 2-13, 2015. http://dx.doi.org/10.1053/j.tvir.2014.12.002

[7] Michele Andreucci, Richard Solomon, Adis Tasanarong, "Side effects of radiographic contrast media: pathogenesis, risk factors, and prevention", BioMed Research International, Vol. 2014, pp. 1-20, 2014. http://dx.doi.org/10.1155/2014/741018

[8] Korea Consumer Agency, "Contrast agent safety survey", 2017.

[9] BOLAS, Nick, "*Basic MRI principles*", Equine MRI, pp. 1-37, 2010.

[10] B. M. Tress, P. M. Desmond, "Magnetic resonance angiography. I. Basic principles", Australasian Radiology, Vol. 37, No. 3, pp. 236-244, 1993. http://dx.doi.org/10.1111/j.1440-1673.1993.tb00063.x

[11] Bosmans H., Wilms G., Dymarkowski S., Marchal G., "Basic principles of MRA", European journal of radiology, Vol. 38, No. 1, pp. 2-9, 2001. http://dx.doi.org/10.1016/S0720-048X(01)00284-4

[12] Dwight G. Nishimura, "Time-of-flight MR angiography", Magnetic resonance in medicine, Vol. 14, No. 2, pp. 194-201, 1990. https://doi.org/10.1002/mrm.1910140206

[13] Özkan Özsarlak, Johan W. Van Goethem, Menno Maes, Paul M. Parizel "MR angiography of the intracranial vessels: technical aspects and clinical applications", Neuroradiology, Vol. 46, No. 12, pp. 955-972, 2004. http://dx.doi.org/10.1007/s00234-004-1297-9

[14] J. W. Choi, H. G. Roh, W. J. Moon, Y. I. Chun, C. H. Kang "Optimization of MR parameters of 3D TOF-MRA for various intracranial stents at 3.0 T MRI", Neurointervention, Vol. 6, No. 2, pp. 71, 2011. http://dx.doi.org/10.5469/neuroint.2011.6.2.71

[15] Juan Alvarez-Linera, Julián Benito-León, José Escribano, Jorge Campollo, Ricardo Gesto "Prospective evaluation of carotid artery stenosis: elliptic centric contrast-enhanced MR angiography and spiral CT angiography compared with digital subtraction angiography", American journal of neuroradiology, Vol. 24, No. 5, pp. 1012-1019, 2003.

[16] Gordon F Gibbs, John 3rd Huston, Matt A Bernstein, Stephen J Riederer, Robert D Jr Brown. "Improved image quality of intracranial aneurysms: 3.0-T versus 1.5-T time-of-flight MR angiography", American Journal of Neuroradiology, Vol. 25, No. 1, pp. 84-87, 2004.

[17] G. B. Pike, B. S. Hu, G. H. Glover, D. R. Enzmann, "Magnetization transfer time-of-flight magnetic resonance angiography", Magnetic resonance in medicine, Vol. 25, No. 2, pp. 372-379, 1992. http://dx.doi.org/10.1002/mrm.1910250217

[18] Nederkoorn P. J, van der Graaf Y, Eikelboom B. C, van der Lugt A, Bartels L. W, Mali W. P., "Time-of-flight MR angiography of carotid artery stenosispp. does a flow void represent severe stenosis?", American journal of neuroradiology, Vol. 23, No. 10, pp. 1779-1784, 2002.

[19] D. S. Willig, P. A. Turski, R. Frayne, V. B. Graves, F. R. Korosec, J. S. Swan, C. A. Mistretta, T. M. Grist, "Contrast-enhanced 3D MR DSA of the carotid artery bifurcation: preliminary study of comparison with unenhanced 2D and 3D time-of-flight MR angiography", Radiology, Vol. 208, No. 2, pp. 447-451, 1998. http://dx.doi.org/10.1148/radiology.208.2.9680574

[20] J. W. Norris, C. Z. Zhu, N. M. Bornstein, B. R. Chambers, "Vascular risks of asymptomatic carotid stenosis", Stroke, Vol. 22, No. 12, pp. 1485-1490, 1991. http://dx.doi.org/10.1161/01.STR.22.12.1485

[21] Sarah Kefayati, David W. Holdsworth, Tamie L. Poepping, "Turbulence intensity measurements using particle image velocimetry in diseased carotid artery models: Effect of stenosis severity, plaque eccentricity, and ulceration", Journal of Biomechanics, Vol. 47, No. 1, pp. 253-263, 2013. http://dx.doi.org/10.1016/j.jbiomech.2013.09.007

[22] J. N. Oshinski, D. N. Ku, R. I. Pettigrew, "Turbulent fluctuation velocity: the most significant determinant of signal loss in stenotic vessels", Magnetic resonance in medicine : official journal of the Society of Magnetic Resonance in Medicine, Vol. 33, No. 2, pp. 193-199, 1995. http://dx.doi.org/10.1002/mrm.1910330208

[23] H. Bosmans, G. Wilms, G. Marchal, P. Demaerel, A. L. Baert, "Characterisation of intracranial aneurysms with MR angiography", Neuroradiology, Vol. 37, No. 4, pp. 262-266, 1995. http://dx.doi.org/10.1007/BF00588328

[24] Mario Cirillo, Francesco Scomazzoni, Luigi Cirillo, Marcello Cadioli, Franco Simionato, Antonella Iadanza, Miles Kirchin, Claudio Righi, Nicoletta Anzalone, "Comparison of 3D TOF-MRA and 3D CE-MRA at 3T for imaging of intracranial aneurysms", European Journal of Radiology, Vol. 82, No. 12, pp. 853-859, 2013. http://dx.doi.org/10.1016/j.ejrad.2013.08.052

[25] Jianhuang Wu, Guiying Liu, Wenhua Huang, Dhanjoo N. Ghista, Kelvin K. L. Wong, "Transient blood flow in elastic coronary arteries with varying degrees of stenosis and dilatations: CFD modelling and parametric study", Computer Methods in Biomechanics and Biomedical Engineering, Vol. 18, No. 16, pp. 1835-1845, 2015. http://dx.doi.org/10.1080/10255842.2014.976812

[26] Sukhjinder S Nijjer, Guus A de Waard, Sayan Sen, Tim P van de Hoef, Ricardo Petraco, Mauro Echavarría-Pinto, Martijn A van Lavieren, Martijn Meuwissen, Ibrahim Danad, Paul Knaapen, Javier Escaned, Jan J Piek, Justin E Davies, Niels van Royen "Coronary pressure and flow relationships in humans: phasic analysis of normal and pathological vessels and the implications for stenosis assessment: a report from the Iberian-Dutch-English (IDEAL) collaborators", European Heart Journal, Vol. 37, No. 26, pp. 2069-2080, 2015. http://dx.doi.org/10.1093/eurheartj/ehv626

3.0T MR system에서 TOF-MRA의 유체속도와 신호소실의 정량분석 : 유속조절팬텀 이용

백상훈,[1] 정진헌,[1] 이예은,[1] 곽민영,[1] 윤준,[1] 정다빈,[2] 오현식,[2,3] 허영철[1,2,*]

[1]을지대학교 보건과학대학 방사선학과
[2]을지대학교 대학원 방사선학과
[3]삼성서울병원 영상의학과

요 약

본 연구의 목적은 TOF-MRA에서 유체속도의 변화와 신호소실의 상관성을 정량적으로 분석하고자 하였다. 유체속도를 제어할 수 있는 팬텀을 자체 제작하여 유체속도를 8.0 ~ 127.3 mc/s까지 총 16단계로 변화시켰다. 3.0T MRI장치를 이용하여 TOF-MRA검사를 하였고 신호소실의 길이와 영상을 유입부, 중간부, 유출부로 분류하여 각 신호강도를 측정하였다. 신호소실의 길이는 유체속도가 127.3 cm/s였을 때 가장 길게 측정되었고 신호강도는 유체속도가 증가할수록 감소하였다($p<0.05$). 유입부(-.547)와 중간부(-.643)는 유체의 속도가 증가할수록 음의 상관성이 있었다($p<0.05$). 결론적으로 유체속도의 증가는 TOF-MRA에서 신호소실을 야기하는 주요한 인자였음을 확인하였다. 추후 혈류속도가 빠른 모델에서 신호소실을 줄이는 시퀀스 및 파라메터를 연구할 때 본 연구가 기초자료를 제공할 것이라 사료된다.

중심단어: 유속증강자기공명혈관조영술, 유속조절팬텀, 유체팬텀, 신호소실, 관류팬텀

연구자 정보 이력

	성명	소속	직위
(제1저자)	백상훈	을지대학교 보건과학대학 방사선학과	학부생
(공동저자)	정진헌	을지대학교 보건과학대학 방사선학과	학부생
	이예은	을지대학교 보건과학대학 방사선학과	학부생
	곽민영	을지대학교 보건과학대학 방사선학과	학부생
	윤준	을지대학교 보건과학대학 방사선학과	학부생
	정다빈	을지대학교 대학원 방사선학과	대학원생
	오현식	삼성서울병원 영상의학과	방사선사
(교신저자)	허영철	을지대학교 보건과학대학 방사선학과	교수