Measurement and Analysis of Carotid/Radial Pulses and Central Aortic Pulse

Jae Joong Im[1], Ran Wei[2], Young Chul Lim[1], Hee Sun Kim[3], Moo Yong Rhee[4],

[1] Division of Electronic Engineering, Chonbuk National University, Jeonju, Korea
[2] School of Electronics and Information Engineering, Tianjin Polytechnic University, Xiqing, Tianjin, China
[3] UnC Co., Ltd., JeonJu, Korea
[4] Cardiovascular Center, Dongguk University College of Medicine, Ilsan Hospital, Goyang, Korea

Abstract. Aortic blood pressure is more meaningful than brachial blood pressures for clinical diagnosis, and ambulatory blood pressure monitoring is better predictor for the outcomes than clinical blood pressure monitoring. However, there are few devices which provide continuous central blood pressures and arterial stiffness noninvasively. In this study, pressure sensors were developed to detect two radial and one carotid pulse waveforms. Central aortic pulse, two radial pulses and carotid pulse were recorded simultaneously during surgery. Parameters were extracted and the relationships among them were examined. Standard deviations for radial and carotid pulse pressures were all within the range of ±5 mmHg for every experimental setup. Augmentation index from aortic pulse showed much lower value than that from the radial sites, and the values of averaged augmentation index showed different trends, which might be caused by the different force applied to the pressure sensor on the carotid artery.

Keywords: Aortic pulse, Blood pressure, Pressure sensor, Carotid pulse, Radial Pulse

1 Introduction

It is worth noting that the systolic blood pressure and pulse pressure are amplified as the pressure waveforms move from the aorta to the periphery [1]-[2]. Arterial pressure is composed of forward and reflected pulse waves. The forward wave is dependent on the elastic properties of the aorta, whereas the reflected waves from the periphery is dependent on the stiffness of entire arterial tree including travel time from the heart to the periphery and the distance to the major reflecting sites [3]. Therefore, it was reported that the central aortic pressure value is the one which determines left ventricular workload and provides better prediction for cardiovascular disease [4].

Since the relationship between the aortic pressure and peripheral pressure is not well established yet, accuracy of noninvasive central blood pressure measurement devices using peripheral arterial pulse waveforms needs to be improved. Moreover, ambulatory blood pressure monitoring (ABPM), which provides 24-hour continuous blood pressure value, is a better predictor of outcome than clinical blood pressure monitoring (CBPM) [5]. Almost all of the conventional ABPM devices provide blood pressure values by employing an inflatable cuff, which is uncomfortable and inconvenient for long time monitoring.

Therefore, it calls for a simple and wearable device to measure central aortic blood pressure noninvasively and continuously. Pressure sensors were developed to detect two radial pulses from the wrist and one carotid pulse waveform. Central aortic pulse waveforms were recorded invasively under the clinical setting. Then, meaningful parameters from the waveforms were extracted and analyzed for comparison.

2 Methods

Piezoresistive pressure sensor was developed for obtaining radial and carotid pulse waveforms. A plastic housing and soft rubber encapsulates each sensor for the protection and lossless pressure delivery. Clip and straps were developed for carotid and radial pulse measurements. Two sensors to measure radial pulse wave on the wrist were separated and located on the radial artery 2cm apart from each other.

Central aortic pulses were acquired invasively using RadiAnalyzer Xpress Measurement System (St. Jude Medical, USA). Two radial sensors and one carotid sensor were placed before the surgery. Before inserting RADI pressure wire into the aorta, pulse waveforms were acquired for 20 seconds. After RADI pressure wire insertion, the aortic pulse waveforms, one carotid and two radial pulse waveforms were recorded simultaneously for 20 seconds from the left side of the body. Then, pulse waveforms from the right side of the body were recorded under the same condition. Finally, both left and right sides of carotid/radial pulse waveforms were acquired again after RADI pressure wire had been withdrew.

Figure 1 represents the parameters extracted from radial pulse and central pulse waveforms. Several researches have documented that the pulse pressures (PP) and augmentation index (AI) derived from the pulse waveforms provide the most important values for clinical diagnosis. Augmentation index(AP/PP × 100%), which depends on the timing of reflected waves, implies the stiffness of the central aorta.

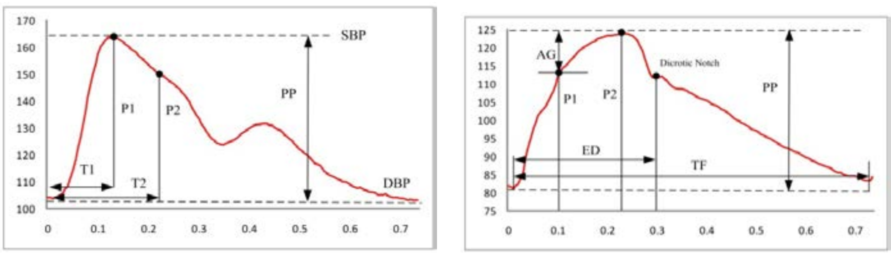

Fig. 1. Feature extraction from radial and central pressure pulse waveforms.

3 Results and Discussion

Averaged parameter values of both PP and AI for the two radial sensors are shown in Table 1. It was found that standard deviations for the values of radial pulse pressure from both sensor1 and sensor2 were within the range of ±5 mmHg for every experimental setup. As expected, PP from aorta showed lower values than that from the radial sites. The values from two radial sites were almost similar regardless of inserting or withdrawing of RADI pressure wire, and AI from aortic pulse showed much lower value than that from the radial sites as expected.

Table 1. Summary of the averaged parameter values for radial and aortic pulses.

	PP (mmHg)	AI (%)	Period
Radial 1	42.5 ± 3.5	91.6± 4.4	Before RADI insertion
	42.8 ± 2.2	91.9± 1.0	During RADI insertion
	52.5 ± 1.9	90.5± 1.0	After RADI withdrawal
Radial 2	47.4±3.0	86.8± 1.3	Before RADI insertion
	48.2± 2.9	88.1± 0.9	During RADI insertion
	52.7± 1.9	88.8± 1.4	After RADI withdrawal
Aorta	43.1 ± 4.6	43.0 ± 3.8	

Averaged values of the parameters from central and carotid pulses during RADI wire insertion were compared to find relationship, and the resulting values are summarized in Table 2.

Results showed that the carotid pulse pressure was lower than central pulse pressure. It probably was caused by the different force applied to the pressure sensor on the carotid artery. The values of averaged augmentation index show different trends and large standard deviation for all three clinical setups. It probably was caused by the different force applied to the pressure sensor on the carotid artery. However, since the outcome shows the consistent results, it is promising for continuing detailed study with enough number of patients.

Table 2. Summary of the averaged parameter values for carotid and aortic pulses.

Parameter (Unit)	Aorta	Left carotid	Right carotid
PP (mmHg)	43.1 ± 4.6	39.7 ± 4.0	38.8 ± 5.0
T1 (msec)	66.3 ± 5.1	101.1 ± 21.0	95.6 ± 17.5
T2 (msec)	196.6 ± 25.6	170.6 ± 34.0	179.9 ± 33.6
TF (msec)	699.8 ± 28.1	666.2 ± 55.6	702.1 ± 42.3
P1 (mmHg)	108.7 ± 3.6	149.1 ± 5.9	144.0 ± 8.2
P2 (mmHg)	127.3 ± 4.4	152.9 ± 6.0	150.3 ± 7.2
AG (mmHg)	18.6 ± 1.4	3.8 ± 2.6	6.3 ± 2.9
AIx (%)	43.0 ± 3.8	9.6 ± 6.3	17.1 ± 8.6
ED (msec)	274.7 ± 24.8	306.6 ± 12.5	307.7 ± 31.3

4 Conclusions

Among various types of blood pressure device, there exit problems of accuracies and convenience for monitoring. It calls for the development of blood pressure monitoring device which provides 24-hour continuous blood pressure without using inflatable cuff. It also is necessary to provide central aortic blood pressure and aortic stiffness noninvasively.

Pressure sensors for obtaining accurate pulse waves from the radial and carotid artery using piezoresistive pressure sensor were developed, and the sensor were sensitive enough to provide accurate arterial pulses. Differences of the parameter values extracted from two different radial arterial sites revealed the similar patterns for both right and left sides as expected. It suggests the possibility of using two radial sensors for applying adequate forces to the artery based on the comparison of outputs form the two sensors.

Additional clinical experiments will be performed with enough data collection for analysis. Moreover, estimation of central aortic pressure waveform from radial artery pulse waves using transfer function will be performed, and direct comparison of pulse waveforms between central aortic pulse and carotid pulse will also be performed. Results of this study could be used as a valuable data for developing 24-hour continuous blood pressure monitoring device without using inflatable cuff for early diagnosis of cardiovascular diseases.

References

1. Topouchian, J., Feghali, R.E., Pannier, B., Wang, S., Zhao, F., Smetana, K., Teo, K., Asmar, R.: Arterial stiffness and pharmacological interventions-the Transcend Arterial Stiffness Substudy (TRANS study). Vascular Health and Risk Management. vol. 3, no. 4, pp. 381--387 (2007)
2. Mattace-Raso, F.U., van der Cammen, TJ., Hofman, A., van popele, N.M., Bos M.L., Schalekamp, M. A.D.H., Asmar, R., Reneman, R.S., Hoeks A.P.G., Breteler M.M.B., Witteman J.C.M.: Arterial stiffness and risk of coronary heart disease and stroke: the Rotterdam Study. Circulation . vol. 113, pp. 657--663 (2006)
3. Robert O. Bonow, Douglas L. Mann, Douglas P. Zipes, Peter Libby:, M.FBraunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 2-Volume Set (Google eBook), Elsevier Health Sciences (2011)
4. Protogerou, A.D., TPapaioannou, T.G., Blacher J, Papamichael C.M., Lekakis J.P., Safar M.E.: Central blood pressures: do we need them in the management of cardiovascular disease? Is it a feasible therapeutic target? Journal of Hypertension. vol. 25, no. 2, pp. 265--272 (2007)
5. O'Brien, E.: Twenty-four-hour ambulatory blood pressure measurement in clinical practice and research: a critical review of a technique in need of implementation. Journal of Internal Medicine. vol. 269, no. 5, pp. 478--495 (2011)