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Professional article ■

Clinical Implication of Pulse Wave Analysis

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SUMMARY

Pulse wave velocity (PWV) is a useful marker of target organ damage in hypertensive patients. It is used as a gold standard because of large body of evidence demonstrating its association with incident cardiovascular disease independently of traditional risk factors. Central blood pressure values (systolic, diastolic blood pressure, augmentation index) could be used in decision making what antihypertensive agent should we use. There are several techniques, most popular of which is applanation tonometry. Recently, normal and reference values have been published.

Key words: **pulse wave velocity, central blood pressure, arterial hypertension**

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INTRODUCTION

Cardiovascular diseases are one of the main causes of death in western industrial countries, as in Slovenia. The exact etiology is not known, but we know that a growing number of risk factors including hypertension, diabetes, smoking, dislipidemia etc. lead to heart atacks, heart failure and stroke. Blood pressure is usually measured by noninvasive auscultatory method introduced by Riva-Roci nad Korotkow more that 100 years ago and a newer oscilometric method. With these methods we are measuring the arterial pressure in brachial artery, since we are using the upper arm cuff. The registration of the arterial pulse was used for clinical diagnosis in the mid to late nineteenth century and the first description of changes in the shape of pulse with age were described (1).

The link between risk factor and cardiovascular disease is arterial stiffness. It can be increased by three mechanisms:

1. A breakdown of elastin fibres;
2. Damage to the endothelium / smooth muscle mechanism;
3. An increase in mean arterial pressure.

The process, by which the arterial system interacts with the left ventricle and coronary arteries, can be demonstrated by analysing aortic root pressure waveform.

Pulse wave velocity measurement

PWV values depend on the algorithm used and path lenght. Different techniques have been compared (2,3). The methods are not interchangeble. The most popular algorithm is intersecting tangent algorithm used by applanation tonometer (Sphygmocor®).

Applanation tonometry

The development of the hand-held tonometry probe means the revival of pulse wave analysis in clinical practice. It is simple to use, noninvasive and accurate method. The principal of applanation tonometry is a partial compression of artery against hard structure. The small sensor detects the force on the artery wall (4,5). We use applanation tonometer produced by Sphygmocor (Figure 1).

The Sphygmocor system incorporates the actual pulse recorded at the radial artery and the properties of the transfer function between the aorta and the radial artery to estimate the central aortic pressure. The radial waveform is calibrated using systolic and diastolic pressures valuse from conventional cuff measurements. An average waveform is calculated from the ensemble average of a series of contigous pulses (6,7).

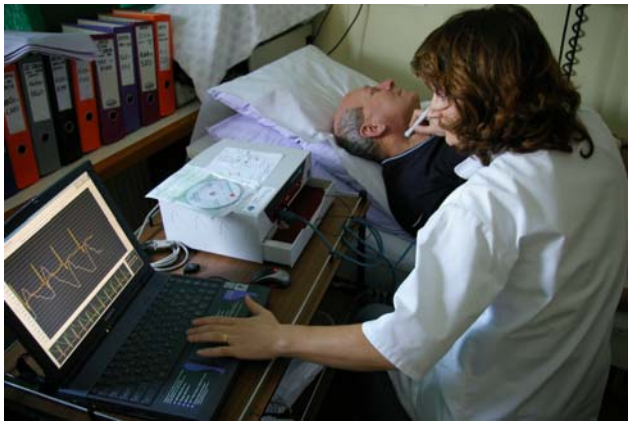

Figure 1. *Applanation tonometer*

Aortic pressure waveform

The shape of aortic pressure pulse is a result of the ventricular ejection and the physical properties of the arterial system. Normally, there is wave reflection. In the absence of wave reflection, the shape of the pressure wave during systole is determined by the ejection wave and the elastic and geometric properties of the ascendenting aorta. If wave reflection occurs during systole, it will increase the pressure against which the ventricle has to eject blood. The knowledge of the pressure waveform will facilitate the analysis of the coupling between the ejectiing heart and pressure load (Figure 2).

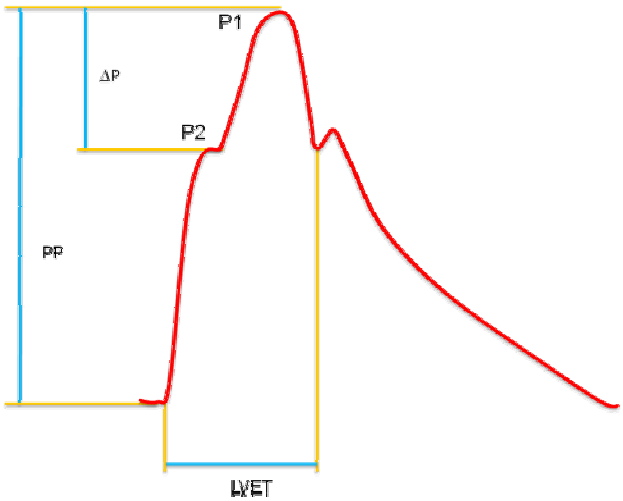

Figure 2*. Pulse wave characteristics*

P1: first systolic ejection, P2: the systolic peak, ΔP: augmentation pressure, LVET: left ventriucular ejection time

Difference between P1 and P2 is absolute augmentation, and augmentation index can be calculated related either to P1 or pulse pressure (systolic blood pressure - diastolic blood pressure). Actual analysis is shown.

Stiffness of arteries has the major effect on aortic pulse wave. In the young it is common to see no or small augmentation as seen on Figure 3 in contarst to older subject (Figure 4).

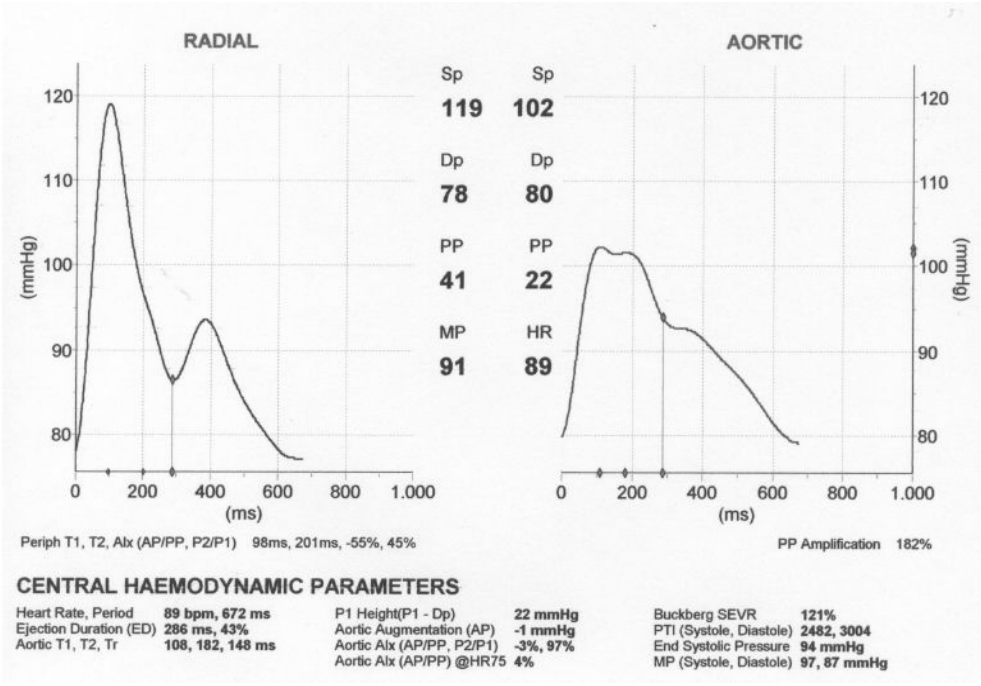

Figure 3. *Pulse wave analysis in a young woman (KR 30 years) (Klinični oddelek za hipertenzijo)*

Radial peak is narrow, late systolic shoulder in aortic pulse is lower than the early systolic peak.

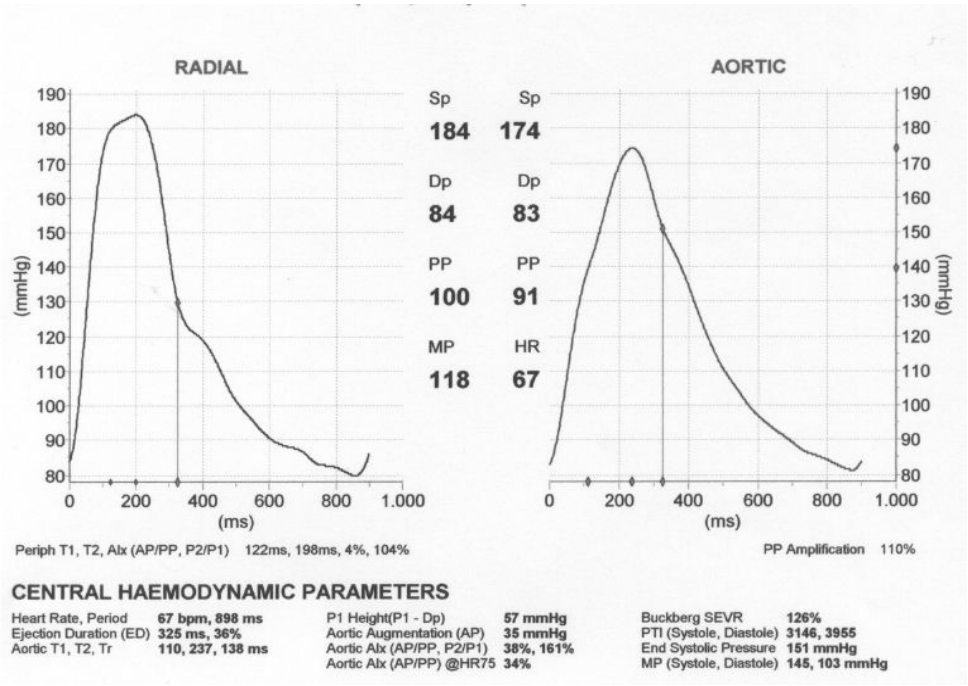

Figure 4. *Pulse wave analysis in an older woman (RT 74 years) (Klinični oddelek za hipertenzijo)*

In older person there is an increased late systolic shoulder in radial pulse and increased late systolic augmentation in the aortic pulse.

Augmentation pressure during systole produces a different loading patteren on the myocardium, even if peak systolic values are identical.

Normal and reference values

Subjects with optimal and normal blood pressure and no additional cardiovascular risk factor have the lowest values for PWV and show the smallest increase in PWV with age (Table 1) (8).

Table 1. *Distribution of pulse wave velocity (m/s)*

Age (years)	Mean ± 2SD	Median (10-90 pc)
< 30	6,2 (4,7 - 7,6)	6,1 (5,3 - 7,1)
30 - 39	6,5 (3,8 - 9,2)	6,4 (5,2 - 8,0)
40 - 49	7,2 (4,6 - 9,8)	6,9 (5,9 - 8,6)
50 - 59	8,3 (4,5 - 12,1)	8,1 (6,3 - 10,0)
60 - 69	10,3 (5,5 - 15,0)	9,7 (7,9 - 13,1)
➢ **70**	10,9 (5,5 - 16,3)	10,6 (8,0 - 14,6)

PWV increases with advanced age and blood pressure levels as shown in Table 2.

Table 2. *Distribution of pulse wave velocity (m/s) according to age and blood pressure category*

Age category (years)	Blood pressure category				
	Optimal	**Normal**	**Highly normal**	**Grade I HT**	**Grade II/III HT**
PWV as mean (±2 SD)					
<30	6.1 (4.6–7.5)	6.6 (4.9–8.2)	6.8 (5.1–8.5)	7.4 (4.6–10.1)	7.7 (4.4–11.0)
30–39	6.6 (4.4–8.9)	6.8 (4.2–9.4)	7.1 (4.5–9.7)	7.3 (4.0–10.7)	8.2 (3.3–13.0)
40–49	7.0 (4.5–9.6)	7.5 (5.1–10.0)	7.9 (5.2–10.7)	8.6 (5.1–12.0)	9.8 (3.8–15.7)
50–59	7.6 (4.8–10.5)	8.4 (5.1–11.7)	8.8 (4.8–12.8)	9.6 (4.9–14.3)	10.5 (4.1–16.8)
60–69	9.1 (5.2–12.9)	9.7 (5.7–13.6)	10.3(5.5–15.1)	11.1 (6.1–16.2)	12.2 (5.7–18.6)
≥70	10.4 (5.2–15.6)	11.7 (6.0–17.5)	11.8 (5.7–17.9)	12.9 (6.9–18.9)	14.0 (7.4–20.6)
PWV as median (10-90 pc)					
<30	6.0 (5.2–7.0)	6.4 (5.7–7.5)	6.7 (5.8–7.9)	7.2 (5.7–9.3)	7.6 (5.9–9.9)
30–39	6.5 (5.4–7.9)	6.7 (5.3–8.2)	7.0 (5.5–8.8)	7.2 (5.5–9.3)	7.6 (5.8–11.2)
40–49	6.8 (5.8–8.5)	7.4 (6.2–9.0)	7.7 (6.5–9.5)	8.1 (6.8–10.8)	9.2 (7.1–13.2)
50–59	7.5 (6.2–9.2)	8.1 (6.7–10.4)	8.4 (7.0–11.3)	9.2 (7.2–12.5)	9.7 (7.4–14.9)
60–69	8.7 (7.0–11.4)	9.3 (7.6–12.2)	9.8 (7.9–13.2)	10.7 (8.4–14.1)	12.0 (8.5–16.5)
≥70	10.1 (7.6–13.8)	11.1 (8.6–15.5)	11.2 (8.6–15.8)	12.7 (9.3–16.7)	13.5 (10.3–18.2)

▪ SD, standard deviation, 10 pc, the upper limit of the 10th percentile, 90 pc, the lower limit of the 90th percentile; HT, hypertension.

CONCLUSION

PWV is a useful marker of target organ damage in hypertensive patients. Measurement is included in ESH/ESC Giudelines for the management of arterial hypertension (9) as a gold standard because of large body of evidence demontrating its association with incident cardiovascular disease independently of traditional risk factors. There are several technics, most popular is applanation tonometry. Recently, normal and reference valuse have been published. Central blood pressure values (systolic, diastolic blood pressure, augmentation index) could be used in decision making what antihypertensive agent should we use.

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KLINIČKA IMPLIKACIJA ANALIZE PULSNOG TALASA

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Sažetak

Brzina pulsnog talasa (BPT) je koristan marker oštećenja ciljanog organa kod hipertenzivnih bolesnika. Koristi se kao zlatni standard zbog postojanja velikog broja dokaza koji ukazuju na njenu povezanost sa incidentnom kardiovaskularnom bolešću nezavisno od tradicionalnih faktora rizika. Centralne vrednosti krvnog pritiska (sistolni, dijastolni krvni pritisak, indeks uvećavanja) se mogu koristiti pri određivanju antihipertenzivnog agensa. Primenjuje se nekoliko tehnika, od kojih je najpopularnija aplanaciona tonometrija. Nedavno su objavljene normalne i referentne vrednosti.

Ključne reči: **brzina pulsnog talasa, centralni krvni pritisak, arterijska hipertenzija**