

APG

(Accelerated Photoplethysmography)

clinical manual



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Chapter 1. Photoplethysmography

1. Definition of photoplethysmography

Photoplethysmography is a wave form signal that indicates pulsation of chest wall and great arteries followed by heart beat, that is, the blood pressure and vascular diameter change with cardiac cycle, and these arterial pulsatile alterations propagating to peripheral vascular system mean "*photoplethysmography*".

The chief aims of "*photoplethysmography*" are observation on mechanical movement of heart and kinetics of blood flow, and *photoplethysmography* manifests the pulsation of chest wall and great arteries followed by heart beat as wave form.

2. Classification of photoplethysmography

Photoplethysmography classifies into two groups in terms of physical characteristics of parameters. One is "**pressure photoplethysmography**", which represents the change of intravascular pressure. The other is "**volume capacity photoplethysmography**", which indicates the change of vascular volume capacity. By using sensory organs in our body, for example finger tip, we can usually sense alterations of various pulsations followed by fluctuating internal pressure of radial artery. The alterations of pressure are detected by specific procedure in which catheter is injected into the radial artery and then pulse change is recorded. This change is "**pressure photoplethysmography**". Unlike this procedure, there is another specific tool that records the dilatation and constriction of artery caused by change of intravascular pressure. *Photoplethysmography* divides into two parts. One is central part. In this part, *photoplethysmography* is measured in aorta, carotid artery and so on. The other is peripheral part, measured in peripheral artery at finger tip or tiptoe. In general, the former is "**pressure photoplethysmography**" while the latter is "**volume capacity photoplethysmography**", but *photoplethysmography* commonly means "**volume capacity photoplethysmography**". *Photoplethysmography* is also classified into three categories by signal processing method for velocity, that is, "**(simple) photoplethysmography**", "**velocity pulse photoplethysmography**", and "**accelerated photoplethysmography**".

In general, *photoplethysmography* represents original wave that is recorded, so this parameter, *photoplethysmography*, has a original characteristic as itself and helps us realize its specificity. However, original *photoplethysmography* has a limitation to help us analyze the course of wave changes just because the original wave is flat. For propping up this weak point, we use the differentiated value of original wave in clinical fields. This differentiated value

indicates "**velocity photoplethysmography**". This value is useful for us to comprehend and analyze the process of pulse wave change which is difficult to be understood in the common photoplethysmography. But, there are limits to understand the process of pulse energy though "**velocity photoplethysmography**" is useful to understand the process of pulse wave change. Therefore, we apply the differentiated value of velocity pulse wave in clinical fields to more specifically realize the process of pulse energy. This ultimate value is called "**accelerated photoplethysmography**".

*The classifications by the region of the body: carotid arterial wave, radial arterial wave, beat wave

*The classifications by the detection methods: pulse pressure wave, volume capacity wave

*The classifications by signal processing: (simple) pulse wave, velocity pulse wave, "accelerated velocity pulse wave"

3. Clinical significances and measurement methods of photoplethysmography

A) Clinical significance

ECG (Electrocardiogram), phonocardiogram and cardiac catheterization have taken major roles on diagnosis of cardiovascular diseases as biomedical engineering has developed rapidly in recent days. However, **photoplethysmography** is very simple parameter and there are many factors affecting the shape of pulse wave, and then **photoplethysmography** has not been considered to be adequate parameter for indicating informations of diseases even if there has been much efforts of former scientists about it. In addition, **photoplethysmography** has been regarded to somewhat be useful for detecting only the limited categories in peripheral vascular diseases. But, based on the fact that it is possible to measure the depression of cardiac strength by palpation of the radial artery, the research on diagnostic approach to *heart failure* or *cardiac reserve force* by utilizing "**volume capacity photoplethysmography**" has been performed. In short, kinetics of blood flow is discrepant from normal value in some disease entities of heart and this discrepancy may give rise to specific alterations of pulse wave. Also, **photoplethysmography** offers informations in the vascular diseases such as occlusive disease of vessels or change of vascular elasticity.

- valve disease, hypertension, arteriosclerosis, arterial disease, thyroid disease, anemia, autonomic nervous dystonia, cardiac reserve force in arrhythmia, whether or not heart failure, assessment of drug potency (for example, digoxin etc.)

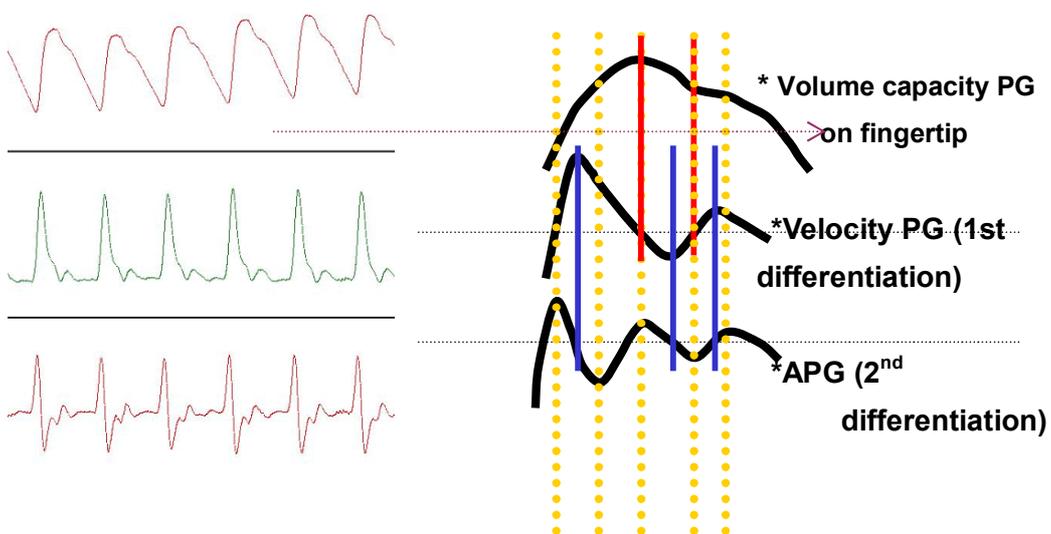
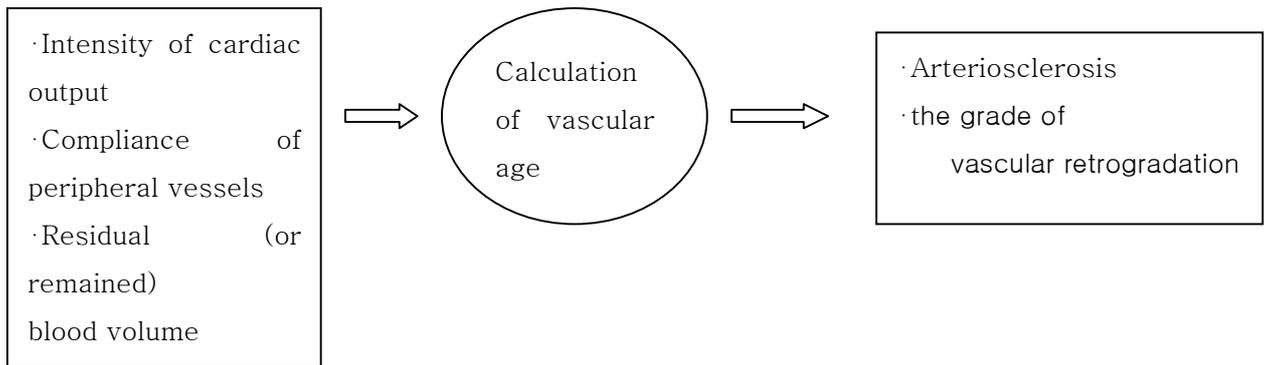
B) Steps of the measurement and Notes.

- a. Remove the irritations like noises, vibrations etc. and take your rest to be measured successfully.
- b. Have a rest before getting start. Anxiousness, tension, and stress affect **photoplethysmography**. The reagent should be measured in resting state since the pulse wave is affected by blood pressure, blood flow etc.
- c. The temperature of a room should be kept at adequate level. If room temperature is higher, peripheral vascular dilatation occur, and if room temperature is lower, muscle spasm may happen. Therefore, these alterations may cause the distortion of recording results.
- d. Your posture for the measurement needs to be supine position, and the location of transducer attached on your arm and finger tip should be kept at the same level in height. If the transducers' location is higher than heart level, the vascular resistance in the arterial blood evoked from heart and flowing to periphery would become higher in systolic phase, and indentation or duplication wave is not clear because of small alterations of volume capacity.
- e. Avoid conditions putting pressure on your arm or finger tip.
- f. Put your finger on the sensitometry lightly rather than heavily. If you add a bit of pressure than optimal value, pulse wave is overestimated, and if you put pressure much more on the sensitometry, pulse wave is underestimated instead.
- g. The altitude changes with position of transducer attached on finger tip. The sensitometry would select tissue which is distributed densely and regularly beneath the fingernail, and would radiate a beam on selected tissue accurately. So, if unpredictable factors disturb this procedure, the sensitometry does not obtain regular results.
- h. Since a manicure on nail causes errors as to the absorbance quantity, it is better to remove the nail polish before getting a measurement.
- i. In the case where skin is pigmented markedly, the absorbance quantity maybe rise and then there is possibilities in which errors maybe take place.

Chapter 2. Accelerated Photoplethysmography

1. Definition of accelerated photoplethysmography (APG)

This is a measurement tool for the grade of vascular retrogradation by differentiating "Volume capacity photoplethysmography" twice on fingertip.

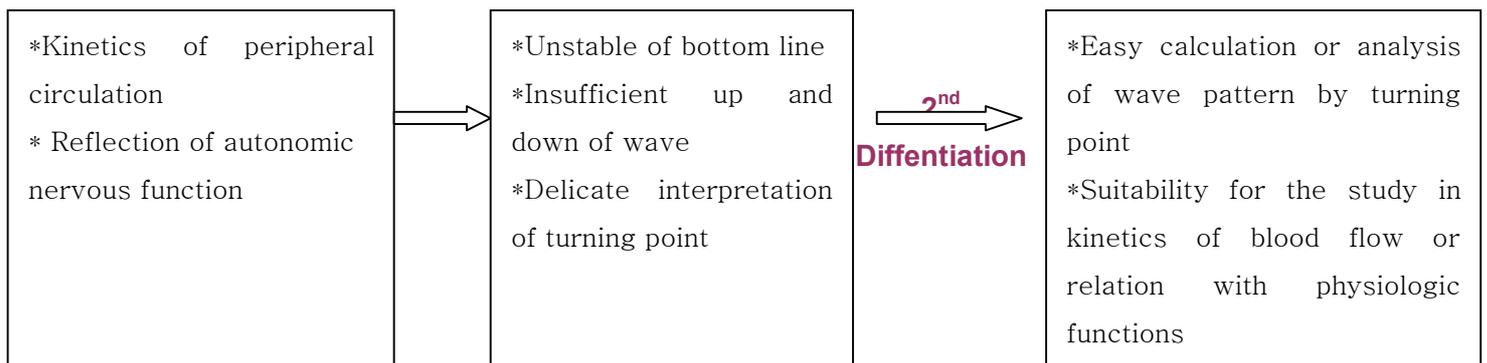


2. Background of invention

<Volume capacity PG
on fingertip>

<APG>

Problems



3. Clinical application

- * Earlier prediction and decision on progression of arteriosclerosis
(Four major predisposing factors of arteriosclerosis : Obesity, Hypertension, Hyperlipidemia, Diabetes)
- * Impediment of peripheral circulation
- * Abnormalities of cardiovascular system (ex. myocardial infarction)
- * Abnormalities of cerebrovascular system (ex. cerebral infarction)
- * Practical use for a health barometer

** Reference materials

(1) Vascular retrogradation and arteriosclerosis

"Aging" goes with retrogradation of most organ in the body, and there is no doubt for the vascular system. With putting on years, our vascular system gradually undergo aging process with progression of vascular stenosis and arteriosclerosis. Arteriosclerosis means that artery become hard (or occur vascular stenosis). Because vessel become gradually hard and lose the

compliance, more vascular pressure inflicts on intraluminal wall of artery at all times even though same blood flow pass by. As a result of this, arterial wall is injured and arteriosclerosis slowly progress. Arteriosclerosis occurs in all aged people. Collagen components of arterial wall increase, or elastic fibers degenerate and decrease in amounts, and then arterial wall become hard and thick.

Meanwhile, arteriosclerosis may develop with no association with age. In this case, for example, smoking maybe damage many intimal cells of arteries and cause dysfunction of these cells, and then cholesterol may deposit on arterial intimal layer and the wall of arteries become thick and hard. Comparing to a running stream, there are much undulation, swift flow and irregular directional flow at the riverbed which have many stones and rocks and so on (arteriosclerosis), and this sort of flow make a swirling torrent or a small waterfall. Such a turbulent flow like this may increasingly damage arterial wall, and lipid particles or platelet are to be deposited again on the arterial wall so that thrombus could develop in this circumstance. Thrombus is the main risk factor of some diseases such as stroke, myocardial infarction and so on.

(2) Earlier detection of vascular retrogradation and arteriosclerosis

The most valuable method to evaluate "vascular retrogradation's grade" and to detect "arteriosclerosis" is the estimation of "arterial compliance" and "peripheral circulation status". In the clinical field, besides this method, there are many evaluation methods such as angiography, sonography and funduscopy. Also, the evaluation could be conducted by synthesizing the various parameters such as ECG findings, blood pressure and hemanalysis results. Even though all these parameters or methods are related with vascular retrogradation and arteriosclerosis, these things do not represent the severity of arteriosclerosis. So, the early detection of arteriosclerosis is difficult until now, and the quantitative analysis of vascular retrogradation is not easy, too. However, by using PG, the estimation of "arterial compliance" and "peripheral circulation status" becomes more easier, and the early detection of "peripheral circulation insufficiency" and "arteriosclerosis" could be possible. As a result of these, specific herb medication and management by patient' predisposition could be available, and medical approaches of this kind are to prompt the blood circulation and to rehabilitate the arterial compliance.

Heart ejects 120(L/m) continuously through aorta to the body. At this time, the ejection from heart is followed by the vascular wave motion which is formed by cardiac pumping. This wave motion is alike to waves seen in the sea, and without substantial obstacles, this wave could be

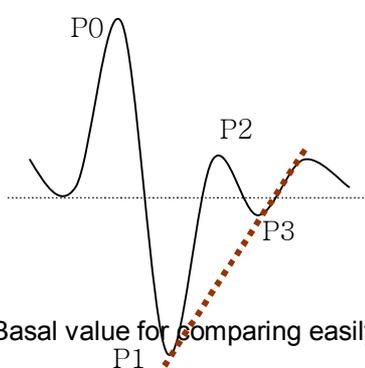
transmitted to the periphery constantly. We can be palpable this pulsation on the wrist, and we call this pulse "Chin-mack(診脈)". Therefore, if we observe the pulse wave on the specific site like fingertip, we could get the overall information about that arterial system. Particularly, since "accelerated velocity pulse wave" represent "vascular compliance" and "status of blood flow", it is a tool to delicately evaluate "vascular retrogradation" and "arteriosclerosis". And this sophisticated tool has a point of excellence what evaluates the present vascular age of reagents on the basis of "accelerated velocity pulse wave" depending on their age because it could analysis vascular retrogradation distinctively.

(3) Four major predisposing factors of arteriosclerosis

Obesity, Hypertension, Hyperlipidemia, and Diabetes are the predisposing factors of arteriosclerosis. These factors are all linked together as to causing vascular diseases. In emergent cases of myocardial infarction, we could see a formal resemblance between them, especially in middle age. If men, they are bull-necked, muscular and fatty build (or obesity), and they have common jobs such as salesmen or officials, and they have often eating out, irregular life-style, and hyperlipidemia.

If arteriosclerosis progress in the cerebrovascular system, the regulation system of blood flow would become weak. Subtle change of blood pressure is reflected in cerebral flow, which influence the cerebral function.

4. Analysis of the wave



P0 : Basal value for comparing easily in wave evaluation

P1 : Initial systolic negative wave (intensity of cardiac output)

P2 : Late systolic re-increased wave (vascular compliance)

P3 : Late systolic re-decreased wave (residual blood volume)

* P1, P2, P3 wave represent the alterations of intra-arterial pressure followed by arterial contraction or dilatation. Especially, P1, P3 are very sensitive of the alterations of intra-arterial pressure, so these manifest remarkably arteriosclerosis.

P1: a progression of arteriosclerosis (organic arteriosclerosis grade)

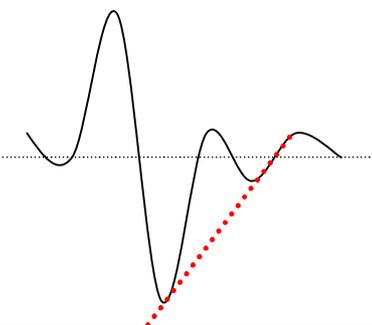
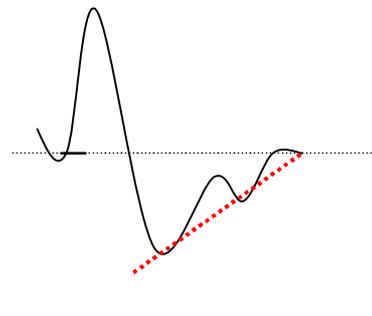
P3: a state of arterial reflex wave (functional vascular dilatation capacity)

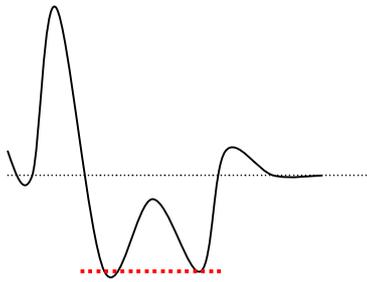
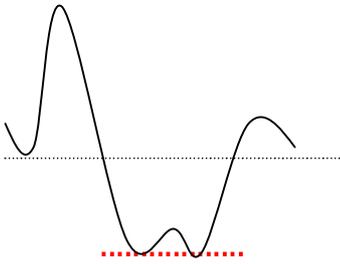
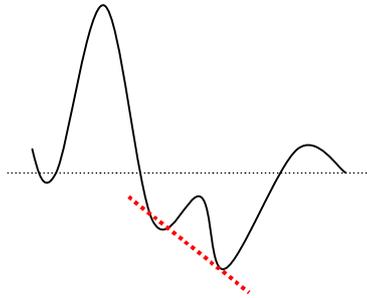
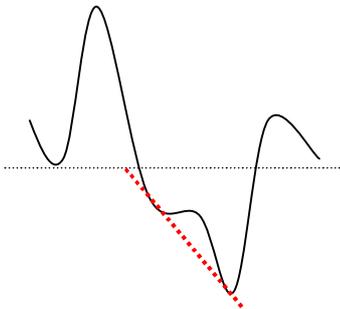
5. Classification of accelerated photoplethysmography

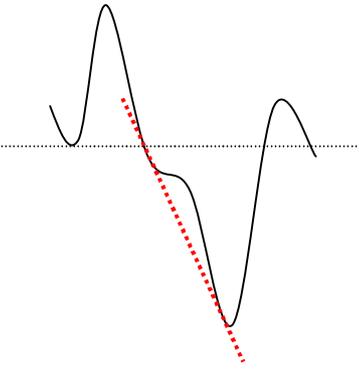
: Approximately, it is classified into 7 classes according to integrity of circulation.

-> As integrity of circulation, the size of P1,P2,P3 maybe change and the gradient of P1-P3 are to shift from "positive" to "0 to "negative" as a wave changes from "normal" to "abnormal-6".

<< Classification of Wave >>

Grade	Wave pattern	Symptoms
Normal		<p>This sort of wave is usually appeared not only in a young and healthy person but also in a person having a good blood circulation. Even if in a middle age, this normal wave is showed in a person being in training.</p>
Abnormal-1		<p>This wave is showed in a person having a slightly bad blood circulation, but still in a good condition. A special feature of this wave is that P2 is below the base line but above P1, and P3 is above P1. As P2, P3 are getting down, it means that a blood circulation is becoming in the bad state.</p>

<p>Abnormal-2</p>		<p>This wave indicates that blood circulation is in the relatively bad state. A marked characteristic is that P3 is descending into the same level as P1 in contrast to normal, abnormal-1 wave.</p> <ul style="list-style-type: none"> ▪Symptoms : hand and foot are getting chilled or cold , a person belonging in this type is vulnerable to get congestion
<p>Abnormal-3</p>		<p>This wave manifests that blood circulation is in the considerably bad state. A marked characteristic is that P2 is in the same level as P1, P3 in contrast to abnormal-2 wave, and becomes indistinct state.</p> <ul style="list-style-type: none"> ▪Symptoms : edema, hand and foot are getting chilled or cold, feeling heavy in the head or feeling like getting a hat on.
<p>Abnormal-4</p>		<p>This kind of wave is appeared in a person having a significantly bad blood circulation. A special feature is that P3 is below P1, and if discrepancy is getting wide, it represents that a blood circulation is gradually becoming bad state.</p> <ul style="list-style-type: none"> ▪Symptoms : abrupt general weakness and pain, skin color abnormality and thermo anesthesia
<p>Abnormal-5</p>		<p>This wave indicates that blood circulation is in the exceptionally bad state. A marked characteristic is that P1 and P2 is almost in the same level, and P3 is in the far lower location than P1, P2. ▪Symptoms : Hand and foot could be blue from complications</p>

Abnormal-6	 An ECG waveform showing a QRS complex with a deep S wave. A red dotted line is drawn from the end of the QRS complex down to the baseline, indicating a significant ST segment depression. A horizontal dotted line represents the baseline.	<p>This wave indicates that blood circulation is in the worst state. In this case, ECG often detects the abnormalities.</p> <ul style="list-style-type: none">▪Symptoms : This condition is liable to infection even a slight injury (or trauma). risks of stroke, dementia due to cerebrovascular abnormalities, this condition does not improve though the medical treatment is being done.
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