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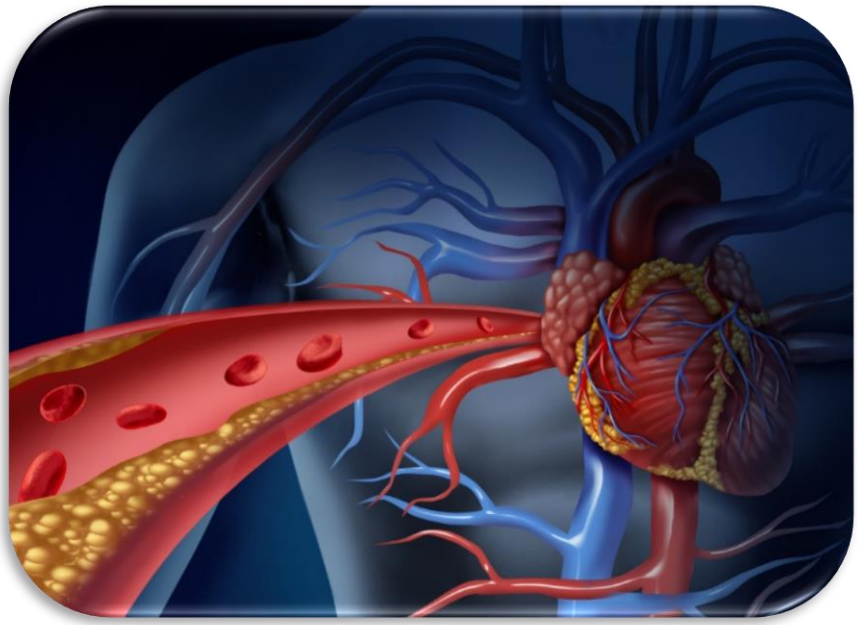
APG as a reflection of vascular status



Dr. P. Kleikers
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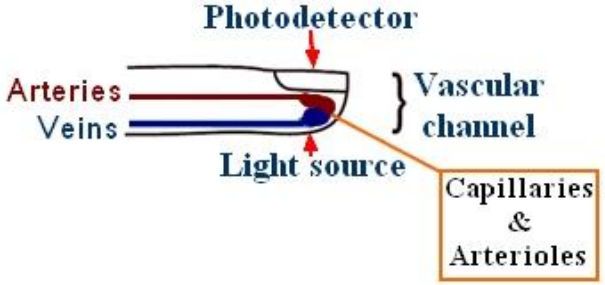
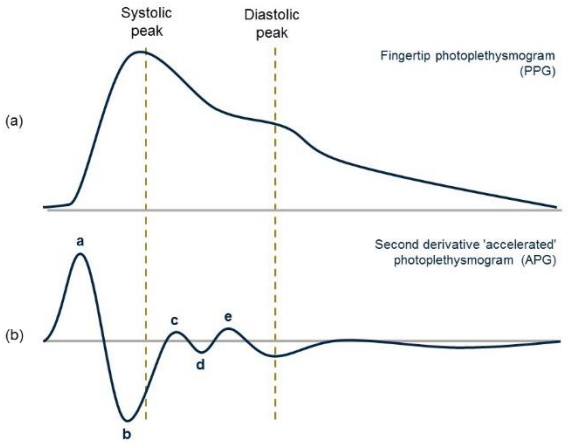
Principles of the APG technique

- APG is the second derivative of the fingertip photoplethysmogram (PPG) waveform (see also at 'APG technique').
  - Non-invasive
  - Pattern of 5 waves visible
- Used to measure vascular stiffness and aging
  - Arteriosclerosis: changes in the arterial wall lead to stiffer arteries with increasing age





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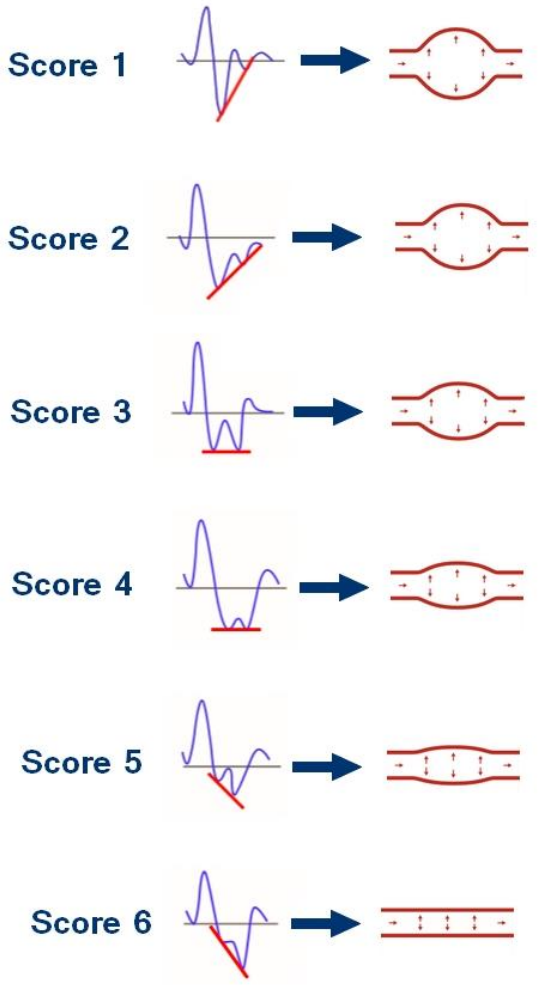
APG and aging & vascular stiffness

- APG wave signals can be used to determine characteristics of vascular aging
- The pattern of 5 waves (a,b,c,d,e) shows characteristic changes with increasing age and increasing arterial stiffness[1].
- Ratios of the five waves change with increasing vessel stiffness
  - The b/a ratio increases with age, reflecting increased arterial stiffness.
  - The c/a, d/a and e/a ratio decrease with aging[2].
  - An aging index ((b-c-d-e)/a) was developed to determine the vascular age using the APG signal[2,3].



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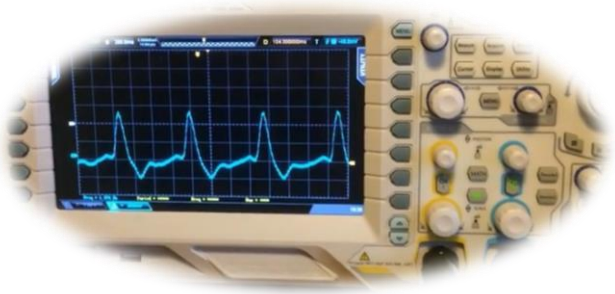
APG and cardiovascular diseases

- APG ratios are correlated with
  - Arterial distensibility[4]
  - Atherosclerotic changes (plaque formation) in the carotid artery[4,5]
  - Blood pressure[3]
  - Gender[3]
- Changes in the APG signal are also correlated with the risk of cardiovascular disease:
  - Framingham risk score[6]
  - Changes in lipid profile and cholesterol, smoking and lack of regular exercise[7]
  - Hypertension and structural changes of the heart[8]



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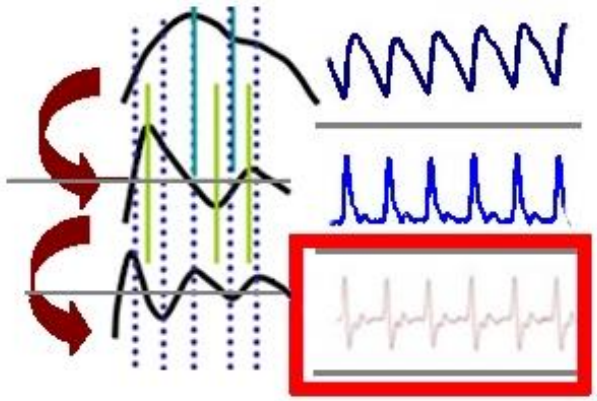
APG: other applications

- APG can also be used for other indications, for example:
  - Characterizing the response of the vessels to vasoactive agents[2,9]
  - Characterisation of heart-rate-variability[10,11]
  - Migraine[12]



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APG versus Pulse Wave Velocity (PWV)

- **APG is a relatively new technique in the cardiovascular field.**
- **The gold standard for measuring arterial stiffness is Pulse Wave Velocity**
  - **Technique depends also on the pulse wave travelling through the vessels.**
  - **PWV= the velocity of the pulse wave to travel a given distance between two sites of the arterial system[13] (figure 1).**

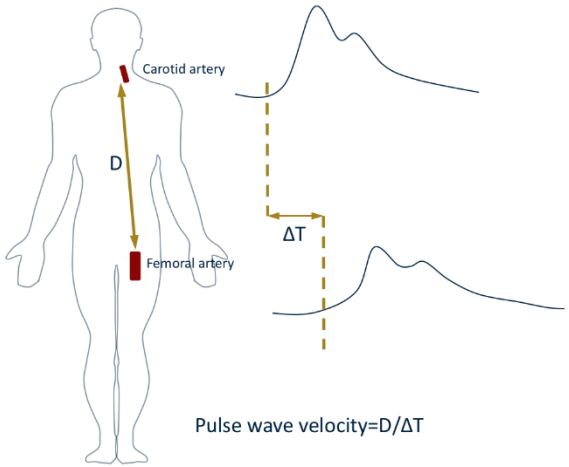

Figure 1 *Schematic representation of Pulse Wave Velocity Measurement from carotid and femoral arteries ΔT=time delay between the foot waves; D=distance travelled by the wave.*

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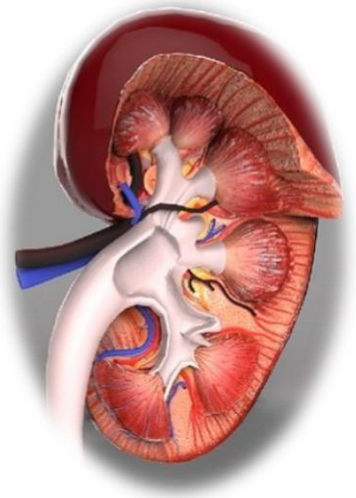
APG versus Pulse Wave Velocity (PWV)

- **Correlation between APG and PWV**
  - **The b/a and d/a ratio and the aging index of APG are correlated to PWV[14].**
  - **In an hypertensive population, both PWV and APG could indicate vascular stiffness and aging[15].**
  - **In a normotensive population, PWV and the APG indices were strongly correlated with age[16].**
  - **In chronic kidney disease patients, APG correlated well with aortic calcification index as a measure of arteriosclerosis[17].**



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APG: conclusion

The APG signal measured at the finger reflects the subject's overall vascular status and can give valuable information about the possible existence of cardiovascular diseases which warrant further investigation by a medical doctor. APG has been shown to correlate well with the gold standard (PWV) and is increasingly being used in the cardiovascular fields to easily and non-invasively measure vascular status.

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For more in-depth discussion, please refer to the scientific publications.

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3: Hashimoto, J. et al. Pulse wave velocity and the second derivative of the finger photoplethysmogram in treated hypertensive patients: their relationship and associating factors. *Journal of hypertension* 20, 2415-2422, doi:10.1097/01.hjh.0000042887.24999.7b (2002).

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For more in-depth discussion, please refer to the scientific publications.

5. Bortolotto, L. A., Blacher, J., Kondo, T., Takazawa, K. & Safar, M. E. Assessment of vascular aging and atherosclerosis in hypertensive subjects: second derivative of photoplethysmogram versus pulse wave velocity. *American journal of hypertension* 13, 165-171 (2000).

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12 Komatsu, K., Fukutake, T. & Hattori, T. Fingertip photoplethysmography and migraine. *Journal of the neurological sciences* 216, 17-21 (2003).

13 Safar, M. E., Henry, O. & Meaume, S. Aortic pulse wave velocity: an independent marker of cardiovascular risk. *The American journal of geriatric cardiology* 11, 295-298 (2002).

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15 Bortolotto, L. A., Blacher, J., Kondo, T., Takazawa, K. & Safar, M. E. Assessment of vascular aging and atherosclerosis in hypertensive subjects: second derivative of photoplethysmogram versus pulse wave velocity. American journal of hypertension 13, 165-171 (2000).

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