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# STRAIN AND STRAIN RATE

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| What is it? | In general, strain is a change in length normalized to the original length and strain rate is the rate at which this change occurs (see figure below).<br><br>**Strain** is the deformation (change in shape) or displacement (motion) induced by an external or internal force. Deformation is secondary to force and depends on load, while motion is the summation of deformation.<br><br>**Strain rate** is the speed of the deformation or the change in strain per time unite.<br><br>The relationship between strain and strain rate is:<br><br>1. Strain (Ɛ) is the temporal integration of strain rate (SR)<br><br>$\varepsilon = \int SR\, dt$<br><br>2. Strain rate (SR) is the temporal derivation of strain (Ɛ)<br><br>$SR = \frac{d\varepsilon}{dt}$<br><br>Normal strain and strain rate (Lagrangian/engineering strain and strain rate) is the linear strain and strain rate and is a change in length relative to baseline length. Natural or true strain (Eulerian (logarithmic) strain) is a change in length relative to the instantaneous length, while natural strain rate also considers the velocity ratio of the object.<br><br>The length ratios are often expressed in percent. Positive strain is lengthening or stretching, and negative strain is shortening or compression, while strain rate is negative during shortening and positive during elongation.<br><br>There are different measures of strain and strain rate such as Longitudinal (linear), volumetric (3D) and shear (parallel) strain. |
| Why do we measure it? | Strain and strain rate are measures of deformation and displacement/motion that describes an objects nature and function. When assessed in the cardiovascular system, for instance, strain and strain rate reveal information on vascular and myocardial stiffness/load and function. |

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<td>How can it be measured</td>
<td>Strain and strain rate can be measured in-vivo by ultrasound using tissue Doppler imaging (TDI) or 2D/3D speckle tracking (ST).<br>TDI is limited by angle dependency, while the 2D/3D ST angle independency results in better reproducibility and clinical feasibility. Both TDI and 2D ST allows for a thorough evaluation of longitudinal, circumferential, and radial strain and strain rate, however, strain and strain rate measurements are load dependent. The out of plane-motion in 2D ST is overcome by implementation of volumetric 3D ST. In clinical practise, for example global longitudinal strain (GLS) including all left ventricular segments is recommended to detect and evaluate myocardial dysfunction.<br><br>Feature tracking or tagging of cine loops from magnetic resonance imaging (MRI) allow for strain and strain rate analysis, however the technique is limited by the need of additional acquisitions, low signal-to-noise ratio, lack of standardization and demanding post-processing. Furthermore, strain can also be derived from computed tomography (CT) imaging.<br><br>In experimental studies and engineering both Sono-micrometry and Strain Gauge can be used to measure strain through acoustic signals or variations in electrical resistance, respectively.</td>
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<td>Where is it measured?</td>
<td>Strain and strain rate analysis is particularly used in the evaluation of vascular and cardiac function. Strain rate can be measured in the arterial wall of for example the aorta and the carotid arteries. In the heart, strain and strain rate can be measured in both left and right ventricular myocardium as well as in the left and right atrial walls.</td>
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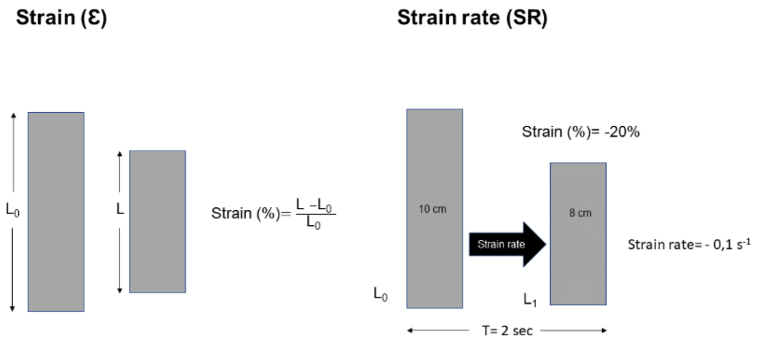
<td>Figure</td>
<td>

Figure legend: Strain (Ɛ) is calculated as the length (L) after deformation minus the original length ($L_0$) divided by the original length ($L_0$).<br>
Figure legend: Strain rate (SR) is the speed at which the deformation occurs.</td>
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| References | Heimdal et al. 1998. DOI: 10.1016/s0894-7317(98)70151-8<br>Smiseth et al. 2016. DOI: 0.1093/eurheartj/ehv529<br>Urheim et al. DOI: 10.1161/01.cir.102.10.1158<br>Amundsen et al. 2006. DOI: 10.1016/j.jacc.2005.10.040<br>Xu et al. 2022. DOI: 10.1007/s00330-022-08629-2<br>Vach et al. 2021. DOI: 10.1038/s41598-021-88294-5<br>Opdahl et al. 2015. DOI: 10.1007/s11886-015-0568-x<br>Lino et al. 2019. DOI: 10.5551/jat.45591<br>Bu et al. 2018. DOI: 10.1161/JAHA.118.008802 |

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https://vascagenet.eu/feedback-for-official-glossary-of-key-terms

* These definitions have been downloaded from https://vascagenet.eu/official-glossary and were released on 1st April, 2023.