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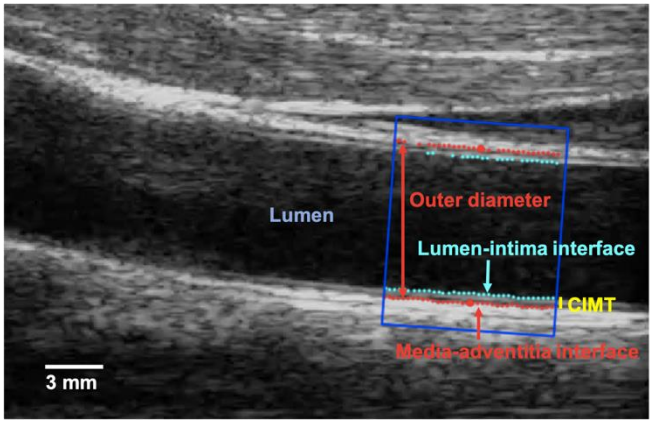
CAROTID INTIMA-MEDIA THICKNESS

What is it?	Carotid intima-media thickness (CIMT), can be visualised by non-invasive B-mode ultrasonography on both walls of the common carotid artery in a longitudinal image as the thickness of the layer between the lumen-intima and media-adventitia interfaces typically recognizable as a double line of the arterial wall. [Touboul 2012] Increased CIMT is associated with the cardiovascular disease (CVD) risk since it is considered a surrogate marker valuable to quantify the atherosclerotic burden in the carotid arteries. [Bauer 2012] Increasing the CIMT correlates with infiltration of lipids and inflammatory cells through the endothelium at the intima-media complex representing an early stage in the atherosclerotic process flanked by inflammation, oxidation, endothelial dysfunction. [Bauer 2012] Cascading processes may induce lesions at the level of the IMT protruding towards the lumen (atheromas) visible as irregularities in the carotid wall which occur in the form of plaques and/or as increased thickness of the intima-media complex. Atherosclerotic plaque formation and thickening of IMT are both indicators used for the cardiovascular risk assessment, they are both identified by ultrasound imaging and provide complementary prognostic information. [Vlachopoulos 2015] However, carotid plaque may represent a later disease stage than increased CIMT; in fact, the latter can also be a phenotype of non-atherosclerotic processes linked to a structural remodeling of the artery wall, reflecting possible differences in localization, risk factors and predictive value for vascular events. [Touboul 2012]
Why do we measure it?	A multitude of prospective cohort studies report increased CIMT values in the presence of high cardiovascular risk burden as well as atherosclerotic disease in individuals with age from children to elderly, thus ascertaining the strong predictive value of CIMT for future cardiovascular events. Indeed, in a meta-analysis of 16 studies with 36,984 participants a 0.1 mm increase in baseline CIMT was associated with a 16% increased risk of future events. [Lorenz 2012] Nevertheless, the predictive power of CIMT for CVD risk needs to be further examined beyond the risk scores and to be demonstrated also in pathological categories such as in patients with diabetes mellitus. The potential of CIMT to reclassify CVD risk was reported in intermediate-risk individuals with a net clinical reclassification index (NRI) of 3.2% in men and 3.9% in women (overall NRI: 0.8%). [Den Ruijter 2012, Vlachopoulos 2015] Moreover, a reduction of 10 μm/year in CIMT progression was reported in a recent meta-analysis to result in a relative risk of cardiovascular disease of 0.91 (95% credible interval, 0.87-0.94), with an additional relative risk of cardiovascular disease of 0.92

	(0.87-0.97), independent of CIMT progression. Modelling estimation assess that interventions reducing CIMT progression by 10 to 40 µm/year would result in decreasing relative CVD risks from 0.84 to 0.63. [Willeit 2020]
How can it be measured?	CIMT can be measured with transcutaneous ultrasonography by Radio-frequency (RF)-data and in B-mode images or clips of the carotid tree as the distance of the intimal to the adventitial layer and is visible as a double line of the arterial wall. Minimum requirements are ultrasound frequencies in the range of 5 -15 MHz, 10 MHz and linear ultrasound transducer is usually preferred with appropriate depth of focus. [Bauer 2012] Originally manual assessment by calipers was adopted; currently, B-mode and RF methods, based on automatic/semi-automatic border detection algorithms, are recommended and can be adopted in clinical practice to faithfully measure CIMT by usually integrating also simultaneous arterial diameter estimation. The two approaches were reported to correlate well in a study including 136 patients diagnosed with cardiovascular disease where RF based measurements provided slightly smaller CIMT values than B-mode analysis (mean difference of 0.045 mm) and comparable intra-patient variation. [Schreuder 2009]
Where is it measured?	The most commonly and easily accessed sites are the common carotid artery (CCA), the inner carotid artery (ICA) and the carotid bulb (CB). CCA has the highest visibility (94-99%) compared to CB (76%-96%) and ICA (54%-81%). The far wall can be better visualized than the near wall (CCA 97% vs 88%, CB 87% vs 80% and ICA 76% vs 49%). The examination is usually performed by a trained sonographer with the person in supine position. Room light is dimmed and temperature of 22-25°C. The head of the patient is rotated by 45° to either the left or the right side. The typical double layer of the intima-media complex is visualized in the longitudinal axis of left and right CCA, each from ear to ear as well as horizontally. An ultrasound arc, the so-called “Meijer-Arc” can be used for longitudinal records in anterior, middle and posterior position. Best visibility was reported at semi-lateral angles, i.e., left side at 120°–150° and right side at 210°–240° angle of insonation. The measurement is typically recorded at the end-diastolic moment (R-wave in the electrocardiogram), when CIMT is thickest, across a 1 cm segment proximal to the bifurcation but measurements, thanks to innovative technology, can also acquired across the complete heart cycle and measurements of all frames are averaged, providing more robust data. Measurements of the intima-media complex are currently analysed with automatic or semiautomatic edge detection software to increase reproducibility compared to manual assessment. [Bauer 2012, Meiburger 2018]

Figure	 Ultrasound image of a longitudinal section of the common carotid artery processed by a contour-tracking algorithm that follows the edges of the lumen-intima and media-adventitia interfaces (light blue and red points, respectively) whose distance is measured as CIMT. [Bianchini 2010]
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