Fluid mechanics delves deeper into the response of fluids to different forces that are exerted upon them. It deals with the relationships that arise between forces, motions, and statical conditions in a continuous material. It looks at concepts like surface tension, flows in bodies, flow stability, fluid statics etc. Fluid mechanics lies in every action that is performed by a person. It has a major influence on cardiovascular health where blood is the fluid traveling through blood vessels, exerting pressure on the walls as it travels. While the function of blood vessels is governed by a bunch of different concepts, two significant ones include shear stress and turbulence. Shear stress is the frictional force that is created as a result of flowing blood dragging across the endothelial cells lining blood vessels. Turbulence is disorder in the flow of blood so instead of smooth and lamina, the flow is chaotic or uneven. These forces can be linked to several cardiovascular diseases, with one of them being atherosclerosis.

Atherosceleriosis is a cardiovascular condition where plaque is formed within artery walls due to the accumulation of materials like fatty deposits, cholesterol, fibrous material and inflammatory cells. The depositing of this plaque essentially narrows the arteries, allowing for much less blood to flow. This not only increases the risks of heart attacks but also strokes and peripheral artery disease. These plaques are most commonly at arterial branches and bifurcations and what's interesting about the blood flow of these points is that here the blood flow becomes more disturbed instead of smooth. So there has been a lot of research in this area to understand how fluid mechanics plays a role in the development of plaque.

Usually blood moves in a smooth laminar pattern that results in stable high shear stress. This laminar flow serves a really important function. It stimulates endothelial cells to release nitric oxide which is responsible for relaxing blood vessels, reducing inflammation and preventing the formation of clots. It also helps maintain vascular health by suppressing genes that are associated with inflammation and oxidative stress. So, in any area with a rather steady blood flow the development of plaque is less likely.

It is when blood flow becomes rather disturbed that issues arise. With a rapid change in Direction comes low or oscillating shear stress in arterial branches and curves. These disturbed flow patterns then damage the endothelial function and we get an inflammatory response. These endothelial cells also become more permeable to low density lipoprotein cholesterol. This allows the cholesterol to accumulate inside the blood vessels. Plaque formation is further promoted when inflammatory molecules and immune cells are immediately recruited to the area. This disturbed shear stress also increases the oxidative stress and then reduces the nitric oxide production which weakens the protective functions of the endothelium

The growth of plaque can then disrupt the blood flow and this creates regions of turbulence. so this disturbed flow promotes the growth of plaque and the growth of plaque further leads to more disturbed flow. These plaques may rupture and cause blood clots. These can trigger heart attacks or strokes and completely block arteries. As a result of this understanding, endothelial dysfunction which is caused by abnormal shear stress is recognized as one of the earliest stages of atherosclerosis development.

So this gives us an idea of how important fluid mechanics is in cardiovascular treatments and engineering in general. Blood flow can also be modeled using computational fluid dynamics and regions that are at high risk for the formation of plaque can be identified and flagged. Furthermore, the main goal when designing vascular grafts and stents is also to minimize the turbulence and restore healthy shear stress patterns. Overall, these principles have improved how we understand and diagnose different cardiovascular diseases along with how they are treated.

1. Nature Reviews Cardiology – Endothelial responses to shear stress in atherosclerosis
2. PubMed – Vascular endothelial responses to altered shear stress: pathologic implications for atherosclerosis
3. Laboratory Investigation – The role of shear stress in the pathogenesis of atherosclerosis
4. 1.1: What is Fluid Mechanics? - Engineering LibreTexts