Why are arteries the size they are?

William P. Santamore, PhD, and Alfred A. Bove, MD, PhD

Departments of Medicine and Physiology
Temple University
3400 N. Broad Street
Philadelphia, PA 19140

Sones performed the first coronary artery angiogram by accident in 1958. While injecting contrast material for a left ventricular angiogram, the catheter slipped out of the ventricle and into the right coronary artery. Sones immediately recognized the advantage of visualizing the coronary artery lumen, and coronary angiography quickly developed (1, 2). Coronary angiography provided the needed diagnosis tool for new therapy, coronary artery bypass surgery (3,4). The most severe lesions could now be quickly identified by the simple percent stenosis measurement (100% x [normal artery diameter – minus minimal stenotic diameter] / normal artery diameter). The percent stenosis measurement is easy to perform, can be visually estimated, and does not require quantification of the coronary artery size. This measurement together with bypass surgery became the clinical standard, which dramatically improved cardiovascular care (5).

Angiographically determined percent stenosis was the unchallenged clinical standard for many years. The validity of the percent stenosis measurement was not questioned despite pathological
examinations of human coronary arteries, which revealed extensive disease, not limited to just the site of the most obstructed portion of the artery (6). Later retrospective examination of coronary angiograms showed that the lesion associated with a subsequent myocardial infarction often was not at the site of the most severe stenosis (7). The opinion of the medical community finally changed with the advent of quantitative coronary angiography and intravascular ultrasound, which unmistakably showed that once a severe coronary artery stenosis occurred, generalized disease was present throughout the vessel (8, 9).

If the normal size of the vessel can not be determined, how can the percent stenosis, even with its limitations, be calculated? Further, how can diffuse coronary artery disease be detected? In this issue of the Journal of Applied Physiology, the study by Choy and Kassab (10) provides answers to these questions and raises new questions. In a simple yet eloquent study, they injected latex material into the coronary arteries of a pig, and compared the artery size to the mass of myocardium perfused by that artery. They established a 3/8 power relationship between artery size and myocardial mass. With new imaging and measuring techniques, the coronary artery size and the mass of myocardium perfused can be readily calculated. Using the 3/8 power relationship will allow accurate determinations of percent stenosis and diffuse coronary artery disease.

While the study by Choy and Kassab shows an empirical relationship between artery size and myocardial mass, it does not answer a more fundamental question why coronary arteries, and for that matter arteries in general, are the size that they are. What is the driving physiological principal determining artery size? Is it a cost factor; the minimal arterial size required to deliver
blood with the lowest pressure drop (11,12)? Does it relate to the maximal oxygen carrying
capacity of the blood? What are the implications for coagulation? Is shear rate the key to
regulating vessel size? The measured shear rates at the endothelial surface of all vessels are
remarkably similar. O’Keefe et al. (13) measured coronary dimensions in human hearts
hypertrophied from valvular heart disease and demonstrated a linear relationship between cross
sectional area of the artery and the myocardial mass supplied by the artery. If however
endothelial cells regulate deformation rather than shear stress, then circumferential strain may be
the key factor (14).

So, why are coronary arteries the size that they are? Although this is seemingly a purely
academic question, the answer will provide valuable clinical insight, possibly leading to novel
diagnosis approaches and new therapies. In this issue of the Journal of Applied Physiology, the
study by Choy and Kassab (10) has provided valuable information about coronary artery size
and, hopefully, will stimulate even more research in this area.
References


