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Thermographic imaging in the beating heart: a method for coronary flow estimation based on a heat transfer model.

Gordon N, Rispler S, Sideman S, Shofty R, Beyar R; Heart System Research Center, Department of Biomedical Engineering, Technion-IIT, Haifa, Israel. Intraoperative thermographic imaging in open-chest conditions can provide the surgeon with important qualitative information regarding coronary flow by utilizing heat transfer analysis following injection of cold saline into the aortic root. The heat transfer model is based on the assumption that the epicardial temperature changes are mainly due to convection of heat by the blood flow, which may, therefore, be estimated by measuring the temperature variations. Hearts of eight dogs were exposed and imaged by a thermographic camera. Flow in the left arterial descending (LAD) coronary branch was measured by a transit-time flowmeter. 20 ml of cold saline were injected into the aortic root (just after the aortic valve) and the epicardial temperature images were recorded at end-diastole, for 20-30 s. Different flow rates were achieved by 1 min occlusion of the LAD, which affected a reactive hyperemic response. The dynamics of the temperature in the arterial coronary tree was obtained by averaging the temperature over an edge-detected arterial segment for each frame. The heat transfer equation was curve-fitted, and the flow-dependent heat transfer index was correlated with the experimentally determined coronary flow ($r = 0.69$, $p < 0.001$). In summary: a method for quantitative estimation of coronary blood flow by thermography and heat transfer analysis was developed and tested in animal experiments. This method can provide important information regarding coronary blood flow during open-chest surgical procedures.