Multi-scale cardiac energetics

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Cardiac energetics encompasses both the mechanical performance of the heart and the metabolic energy expenditure that funds it. The qualifier multi-scale indicates that measurements are averaged in both time and location.

Our group studies energetics at whole-heart, tissue (trabecula) and mitochondrial levels, measuring oxygen consumption, heat production and ATP flux, respectively. For whole-heart and trabecula experiments, our focus is on indices of efficiency, respectively the ratio of pressure-volume or force-length work to the volume of oxygen consumed or the quantity of heat produced.

Whole-heart oxygen consumption is given by the product of coronary flow and the arterio-venous difference of oxygen content in the coronary circulation, following correction for the diffusive exchange of oxygen across the epicardial surface. Trabecula heat production is derived from the product of the flow of superfusate and the difference of temperature between downstream and upstream arrays of thermopiles. Mitochondrial efficiency is determined by simultaneously monitoring oxygen consumption and ATP production in phosphorylating cardiac tissue (either homogenised or saponin-permeabilised). Oxygen uptake is assessed in high-resolution oxygraphs and ATP accumulation is detected using the fluorescent indicator Mg^{2+}-green. The net production of reactive oxygen species (ROS) is measured in order to account for the potential loss of electrons that would otherwise contribute to maintenance of the mitochondrial membrane potential and proton motive force. ROS production, plus leakage at ComplexI and ComplexII are added to the measured oxygen consumption to provide a value that can be compared to that measured in the whole-heart.

We find that leakage at ComplexII is sufficient to detract from mitochondrial efficiency and that estimates of mechanical efficiency calculated from measuring heat production of isolated trabeculae are in good agreement with those calculated from the rate of oxygen consumption of whole-heart preparations.