SWITCH FROM VOLUME PUMP TO PRESSURE PUMP VENTRICLE: A MORPHODYNAMIC STUDY IN THE EUROPEAN EEL (*Anguilla anguilla*)

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Due to its structural and functional plasticity the fish heart ventricle adapts to volume and pressure hemodynamic loads by distinct chamber remodellings (Tota and Gattuso, 1996). This can be best illustrated by ranking elasmobranchs and teleosts on the basis of the relative contribution of pressure and volume to the stroke work. The spectrum of cardiac dynamic patterns obtained allows to distinguish between heart ventricles producing mainly pressure work (prototype: tuna) and those producing mainly volume work (prototype: Antarctic icefish) (Tota and Gattuso, 1996). This adaptational flexibility of the ventricle chamber is also illustrated by some fish species that either by growing or under particular environmental challenges can move from one ventricular pattern to another. As a paradigm of this point we have studied cardiac rearrangements in fresh water eels (*Anguilla anguilla*). Changes in mechanical cardiac performance and heart morphology relative to body growth were analysed in juvenile (96.8 ± 27.5 g body weight, mean ± SD) and adult (656 ± 12 g body weight, mean ± SD) fish. Cardiac performance, assessed using an *in vitro* isolated working heart preparation (Imbrogno et al., 2001), showed similar Frank-Starling responses in the two groups. However, while the adult eel hearts were able to maintain stroke volumes (SV) up to an afterload of 6 kPa, the juvenile fish showed a rapid decrease of SV when afterload was increased above 3 kPa. Thus, the adult fish appears better suited to maintain cardiac output in relation to increased outout pressure. Increases of either the preload or the afterload did not significantly alter heart rate in the two groups. Morphometric evaluation was achieved by histology, transmission electron microscopy and image analysis. Both juvenile and adult show a typical mixed type of ventricle (compacta + spongiosa). The ventricular growth was achieved by increasing both the compacta and the spongiosa without a corresponding increase of the ventricular lumen. In fact, the surface area of the lacunary spaces was relatively lower in the adult ventricle with respect to the juvenile. The whole adult ventricle was characterised by a higher number of smaller myocytes than the juvenile counterpart. Thus, hyperplasia of the existing myocytes can be considered a major mechanism for the increase of the ventricular mass. In contrast to the adult, in the juvenile ventricle the compacta showed a lower vascular supply, as indicated by the significantly higher myocardium/vessel ratio. The ventricular myocardial growth is paralleled by enlargements of both the myofibrillar and the mitochondrial compartments.

In conclusion, the morphodynamic analysis of juvenile and adult hearts of *Anguilla anguilla* illustrates how the ventricle pump is able to operate in a very flexible manner in relation to the growth of this teleost. On the basis of its mechanical behaviour the juvenile heart ventricle, also due to its relatively larger lacunary space, is better designed to produce volume work. In contrast, the adult ventricle appears better suited to produce pressure work. This shift from volume pump to pressure pump ventricle is accompanied both in the compacta and spongiosa by myocardial remodelling partly due to hyperplasia, together with enlargement of the myofibrillar and mitochondrial compartments. The adult heart ventricle exhibits also an increased vascularization to match the enhanced contractile demands.

References

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