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Guilhem Poy, Étienne Lelievre, Daniel Alexandre, Rémi Mérindol. Mecanocardiography and capillary pressure measurments in fish embryos by nanoindentation. symposium d'imagerie et analyses des mouvements et déformations, France Life Imaging, Nov 2024, Montpellier, France. hal-04808660

**HAL Id: hal-04808660**

<https://hal.science/hal-04808660v1>

Submitted on 28 Nov 2024

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## Mecanocardiography and capillary pressure measurements in fish embryos by nanoindentation

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Most of our knowledge about how the body functions comes from studies carried out on humans or medium to large animals. However, more than 90% of animal biomass is made up of animals weighing less than one gram, whose physiology remains largely unknown, as is that of the embryonic and larval forms of large animals. The difficulty in studying major physiological functions in small animals comes from the limitations of our measuring instruments. To gain insight into the cardiovascular physiology of fish embryos we use nanoindentation and spinning-disk confocal microscopy to obtain quantitative measurements of volume and force variations in zebrafish embryos and larvae. Nanoindentation is a technique designed to probe the elastic modulus of soft materials by pressing a spherical glass probe (6 to 200  $\mu\text{m}$  in diameter) into the surface of the material. The device measures the indentation of the sphere and the compressive force exerted via the deflection of a rod of known stiffness. This equipment can reproducibly indent a wide range of materials with moduli ranging from 1 Pa to 10 GPa and measure forces ranging from 20 pN to 2 mN. We used a nanoindenter coupled with microscopy (Fig. 1) to measure the mechanical activity of the heart of a three-day-old zebrafish embryo. Figure 2 shows what we believe to be the mechanocardiogram of the smallest animal (3.5 mm, approximately 1 mg) ever recorded to date. We were also able to measure periodic pressure variations on a superficial capillary with a diameter smaller than that of a red blood cell.

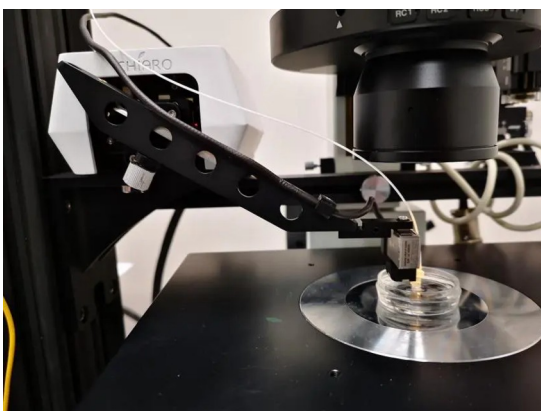


Figure 1: Chiaro nanoindenter mounted on the spinning disk microscope

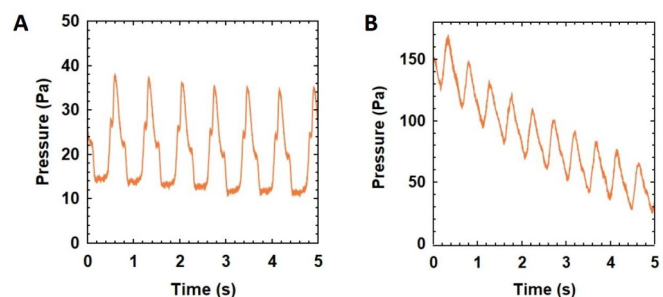


Figure 2: Mechanocardiogram (A) and capillary pressure variations (B) of a 3-day-old zebrafish embryo obtained by nanoindentation