Cardiac stem cell mechanosome and mechanosensitivity develop with differentiation

A. Mauretti1, N.A.M. Bax1, M.J. Goumans2, C. Sahlgren1, C.V.C Bouts1
1 Department of Biomedical Engineering, Eindhoven University of Technology
2 Departments of Molecular Cell Biology and Center for Biomedical Genetics, Leiden University Medical Center

Introduction
Stem cell mechanosensing and mechanoresponse is crucial for tissue regeneration in mechanically functional organs like the heart. However, very little is known about how cardiac resident stem cells, such as cardiomyocyte progenitor cells (CMPCs), sense and respond to the mechanical stimuli provided by the beating heart. Thus, the complex of cellular structures relevant for mechanosensing, made of focal adhesions (FAs) and actin stress fibers, the 'mechanosome', needs to be explored. Identifying the key players and the underlying mechanisms of cardiac stem cell mechanotransduction is essential to achieve optimal migration and integration of endogenous cardiac cells into the injured site. Here we demonstrate that the mechanosensitivity of CMPCs relies on the mechanosome, which develops with early differentiation.

Materials and methods
Cardiomyogenic differentiation of human L929 CMPCs was induced by biochemical stimulation for 14 days (predifferentiated CMPCs) [1]. Uniaxial cyclic strain (10% at 0.5Hz) was applied for 48h to undifferentiated (undiff) and predifferentiated (prediff) CMPCs seeded on collagen IV-coated Bioflex membranes. Unstrained samples were used as control.

CMPCs respond to mechanical cues upon differentiation

Figure 1: Mechanosensitivity is developed with differentiation in CMPCs. Upon cyclic strain, undifferentiated CMPCs (undiff) kept a random orientation, whereas predifferentiated CMPCs (prediff) reoriented perpendicularly to the direction of the strain after 2 days. Representative fluorescent images (calcein), frequency distribution and polar plots display the cell orientation distribution corresponding to each group. Scale bar indicates 400μm. Results are expressed as mean ± SD (N=16-23).

Conclusions and outlook
In conclusion, we showed for the first time that the CMPC mechanosensing apparatus in direct contact with the ECM, the mechanosome, only develops upon differentiation, and allows differentiating CMPCs to align in response to uniaxial strain. This suggests that the lack of a developed mechanosome in undifferentiated CMPCs shields them from the mechanical environment of the beating heart, whereas differentiating cells can sense and respond to cyclic strain by aligning.

References:

Contact: Arianna Mauretti
a.mauretti@tue.nl

Figure 2: CMPCs develop the mechanosome upon early cardiac differentiation. A) Immunofluorescence images show the expression of vinculin (VCL), integrin-linked kinase (ILK), and phosphorylated focal adhesion kinase (pFAK) in undifferentiated (undiff) and predifferentiated (prediff) CMPCs 24 hrs after seeding and before strain application (day0). Scale bar 100μm. B) Gene expression of cardiac troponin T (cTnT), VCL, ILK and FAK at day0. Results are expressed as mean ± SD (N=3).

Figure 3: The mechanosome development is not induced by external mechanical stimuli. Immunofluorescence stainings of vinculin (green) and F-actin (red) at day1 and day2 of straining, did not show differences between unstrained and strained samples in both undifferentiated (undiff) and predifferentiated (prediff) CMPCs. Results are expressed as mean ± SD (N=3).