Introduction
Understanding and modeling liver biomechanics represents a significant challenge due to the complex nature of this organ. Several methods and models based on direct measurements on the liver (e.g. rheological, compressive or indentation tests) or image-based techniques (e.g. magnetic resonance or ultrasound-based elastography) are reported in literature to characterise the liver viscoelastic behaviour in-vitro or in-vivo [Marchesseau et al., 2010]. Unfortunately, there is no consensus on liver viscoelastic properties, and results are strongly dependent on adopted testing method, sample type, status and testing conditions. We focused on in-vitro unconfined bulk compressive tests for deriving liver viscoelastic parameters in the linear viscoelastic region (i.e. small strain region).

Methods
Cubic liver samples (1 cm$^3$) were collected from 1 year old healthy pigs avoiding Glisson’s capsule and macroscopic vasculature. Samples were equilibrium swollen in PBS 1X and then tested at room temperature keeping them partially immersed in PBS to preserve their hydration. Samples were compressed at different strain rates (i.e. 0.01, 0.02, 0.03 s$^{-1}$) using a Zwick/Roell ProLine Z005 equipped with a 10 N load cell to obtain ε̇M dataset. A Generalized Maxwell (GM) model with one or two spring-dashpot series arms in parallel to a pure spring were used to fit experimental stress-time series. DMA analysis was performed using the GABO Eplexor 150 N. The frequency dependence of the compressive modulus, $E(f)$, was assessed in the range 0.5-50Hz. $E(f)$ was reconstructed via a step analysis performing several frequency sweep tests at specific $f$ (i.e. 0.5, 1, 2, 3, 5, 50 Hz) to avoid significant sample deterioration observed due to long testing duration.

Results
Instantaneous and equilibrium compressive moduli ($k_{inst}$ and $k_{eq}$) as well as characteristic relaxation times ($\tau_1 = \eta_1/E_1$, $\tau_2 = \eta_2/E_2$) estimated with ε̇M are summarised in table 1, showing that liver behaves like a lossy system (justified by the absence of the Glisson’s capsule) and suggesting that one viscoelastic arm is enough to describe its linear viscoelastic behaviour. Hence, a 1-arm GM model was used to fit $E(f)$ obtained from DMA measurements (Table 1).

Discussion
$k_{inst}$ estimated with DMA was significantly higher than that obtained using the ε̇M mainly due to the minimum contact force required by the former (~ 0.01 N) that causes a pre-strain of about 10% on tested samples. The different testing conditions also affected the characteristic relaxation time which was found to be significantly lower than that estimated with ε̇M. In conclusion, even though step analysis did not significantly degrade samples during the test, we believe that ε̇M gives better results since it avoids sample pre-stress.

References
Tirella et al., submitted.