Purpose:
The purpose of this study is to evaluate the impact of motion on scanning beam delivery in synchrotron-based spot-scanning proton therapy.

Methods:
A MatriXX 2D ion chamber array detector was placed on a moving platform with 19 cm of solid water for buildup. The platform was moved perpendicular to the beam direction in a simulated breathing pattern using a computer controlled stepping motor. A 10x10cm2 uniform field was delivered using a 173.7MeV beam with an approximately 20 mm spot size (FWHM in water) and 8 mm spot spacing. The delivery time was 1.2 sec/paint, 1-4 repaints were studied. The treatment field was delivered at different motion amplitudes: A=0 (reference), 3, 5, 10 and 20 mm and motion cycles T=3s and 5s. We also tested the starting phase effect by starting the beam at different phases of the motion cycle. In each case the dose distributions under motion were compared to the reference.

Results:
In the presence of motion, the delivered dose pattern to a moving phantom is typically skewed and non-uniform. However, if the motion amplitude was less than 5mm, there was less dosimetric impact (<1% difference in homogeneity) regardless of motion cycle, number of repainting, and the beam starting phase conditions. However there were 6.9% and 27.9% dose difference in homogeneity compared to the reference for 10mm and 20mm motion amplitudes. We found that the starting phase had an impact on the shape of the delivered dose pattern. Multiple repainting minimized but not eliminated the dose pattern distortion caused by different starting phases.

Conclusions:
Delivered dose pattern can be distorted by the interplay effect of patient motion and scanning beam delivery. However, when the spot size (20mm FWHM) and spacing (8mm) are appropriate, the delivered dose pattern can tolerate non-anticipated motion up to 5mm.