# Quantifying Respiratory-induced Prostate Motion using Continuous Real-Time Tracking Technology

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## Background

Prostate positional variability can alter the effectiveness of radiation therapy when precise target location is unknown. Traditionally, PTV margins are designed to compensate for inter-fraction prostate setup variability. PTV margins may be reduced when using daily image-guidance. More recently, the dosimetric relevance of intra-fraction prostate motion has been recognized, and may be compensated for by continuous real-time adaptive radiation therapy afforded by the Calypso® 4D Localization System. As of today, sparse data is available regarding the magnitude and clinical relevance of high-frequency respiratory-induced prostate motion. The specific aim of this analysis was to quantify respiratory-induced prostate motion using electromagnetic continuous real-time tracking technology.

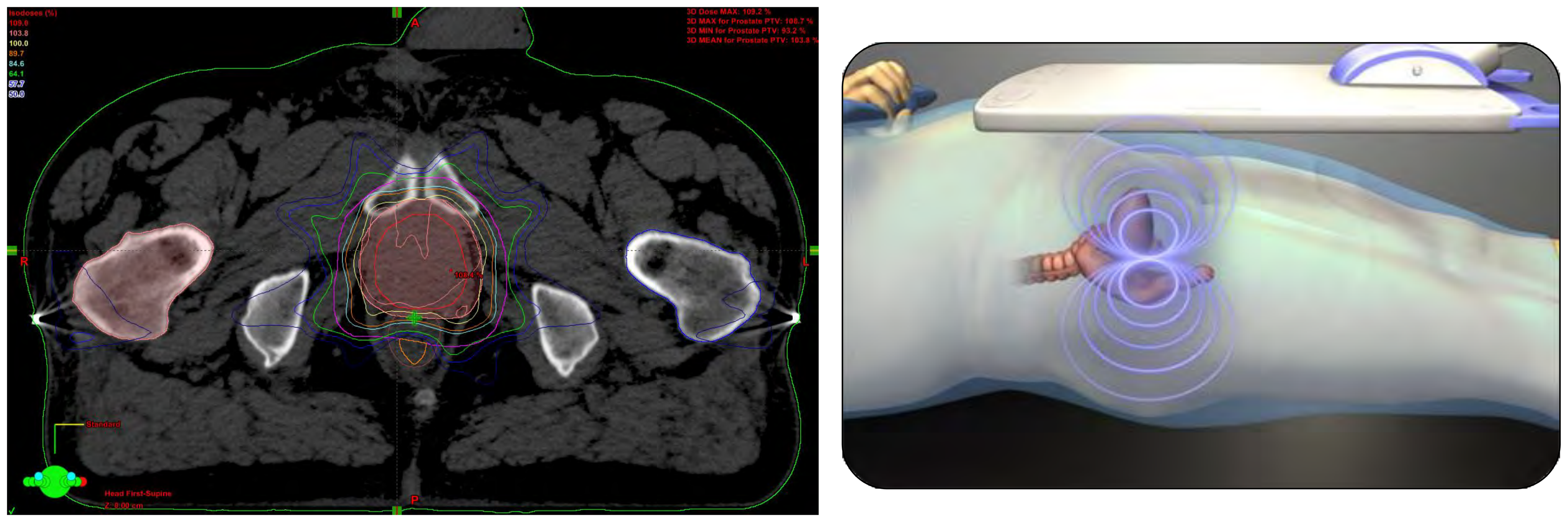

**Figure 1. a) Prostate IMRT plan b) Real-time tracking with radiofrequency technology.**

## Methods

In twenty patients, prostate motion during radiation delivery was measured using the Calypso System. Prior to radiotherapy planning, three Beacon® transponders were implanted in the prostate and used for daily localization and continuous real-time positional tracking. Motion tracking reports were generated electronically. Respiratory motion was cross-verified using the clinically tested Varian Real Time Position Management System™ (RPM system). Four hundred fifty motion traces were analyzed.

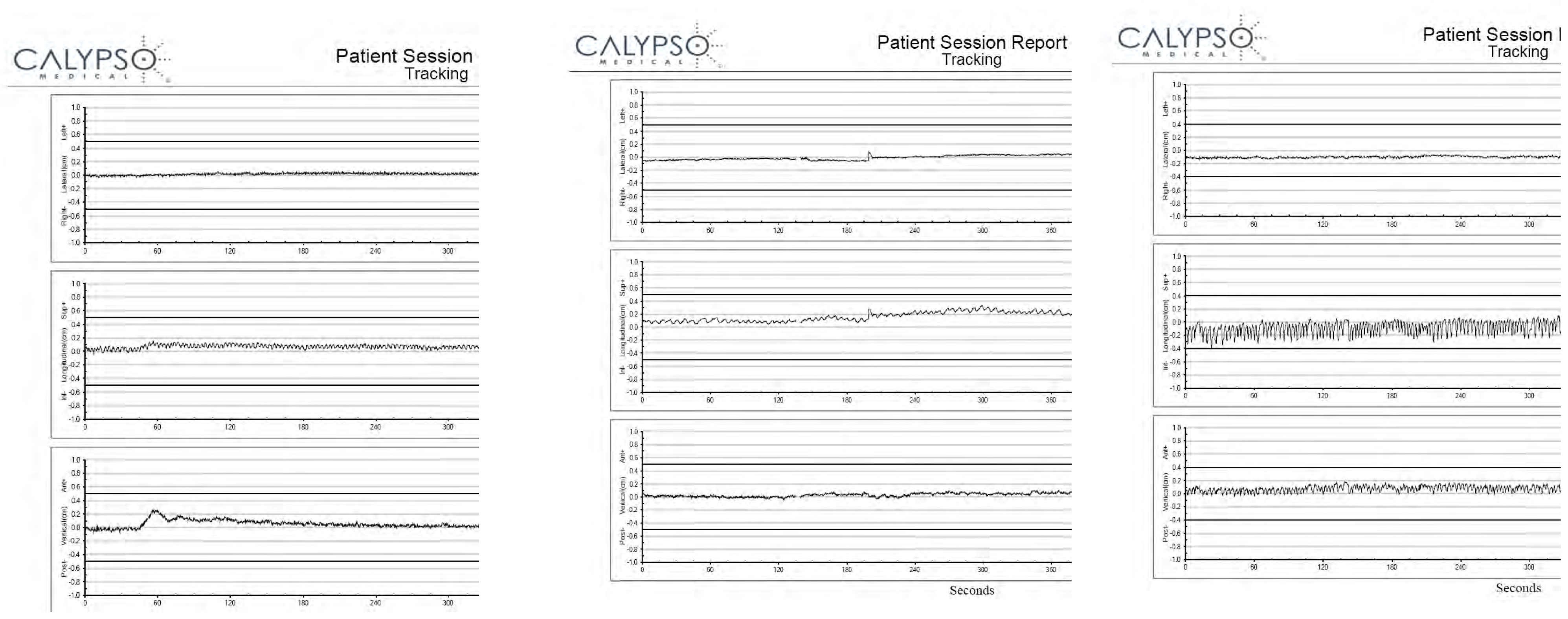


**Figure 2. Example of Calypso® tracings demonstrating respiratory variation in position**

## Results

Ninety-five percent of analyzed real-time motion tracking traces demonstrated identifiable respiratory-induced prostate motion (high-frequency motion >0.5 mm). The observed frequency of respiratory motion correlated with the respiratory frequency derived from the RPM system. The frequency and magnitude of prostate respiratory motion was found to be patient specific and relatively consistent over a course of external beam radiation. Cranio-caudal prostate respiratory motion was largest, followed by anterior-posterior movement. Respiratory-induced lateral motion never exceeded 0.5 mm. In 14 patients respiratory-induced prostate motion exceeded 1 mm over 75% of the time (mean 1.3 mm). The largest measured amplitude of respiratory motion was 2.0 mm.

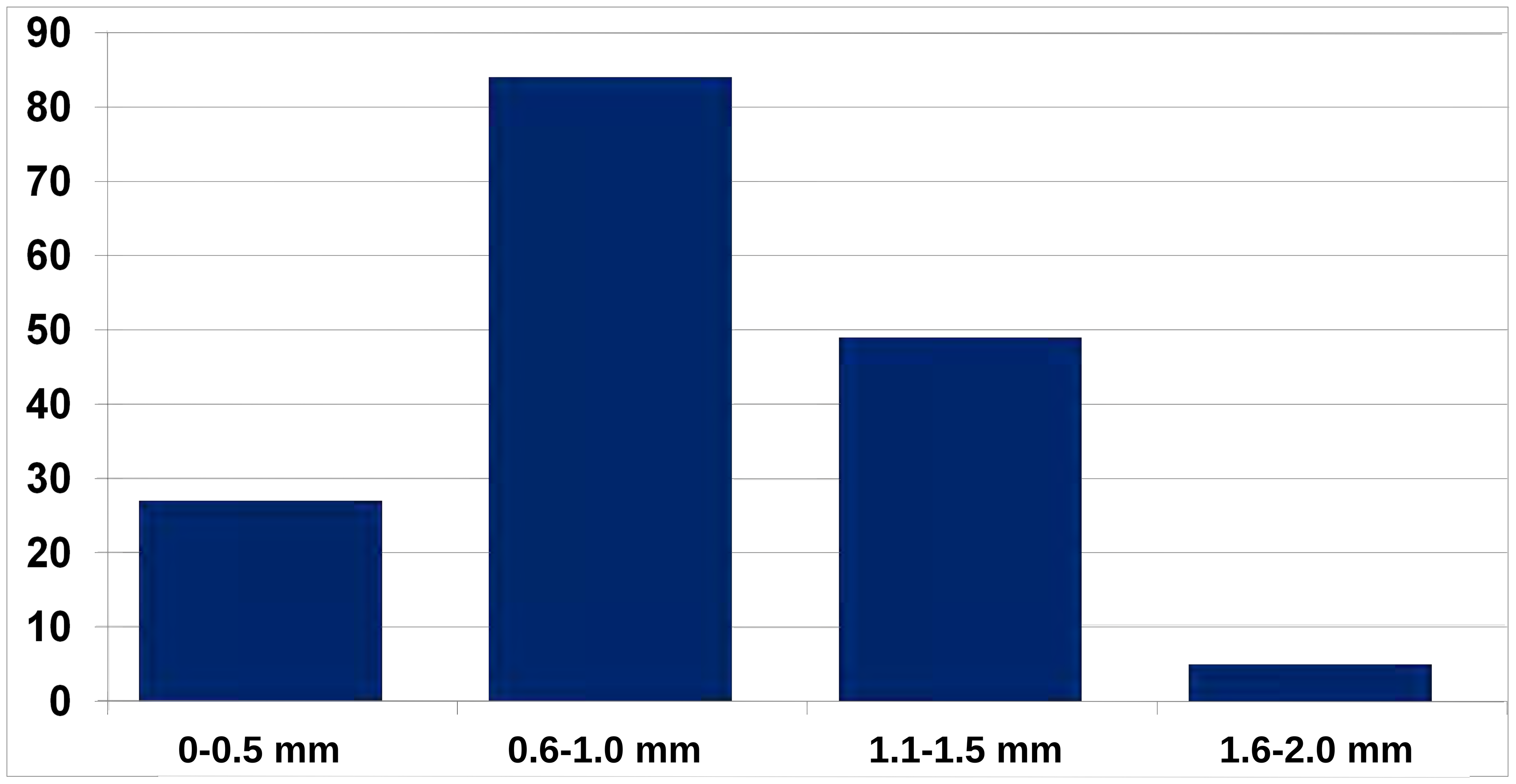


**Figure 3. Number of respiratory-induced motion events in cranio-caudal direction, per magnitude grouping. Mean = 1.3 mm. Max = 2.0 mm.**

## Conclusion

Electromagnetic prostate positional tracking during continuous real-time adaptive radiation therapy delivery allowed identifying respiratory-induced high-frequency intra-fraction prostate motion. The observed respiratory-induced motion was larger than previously reported in the literature, where maximum motion of less than 1 mm was described. While the observed motion was small relative to the inter-fraction setup variability of the prostate, individual respiratory-related prostate motion of up to 2.5 mm should be considered when using very narrow PTV safety margins for prostate external beam radiation treatment.

### References

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