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Tracking of moving fiducial markers during radiotherapy using a CMOS active pixel sensor.

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In order to minimise the dose delivered to healthy tissue during radiotherapy treatment of a moving tumour, it is first necessary to accurately measure tumour position as a function of time. For example, a portal imager can be used to detect surrogate markers implanted around the tumour in order to track the tumour with a moving collimator. Lung tumours can move at up to ˜20 mm/s, requiring a sampling rate of 20 Hz to achieve mm accuracy. However the passive a-Si flat panel imagers (FPIs) available with current linear accelerators operate at ˜2-10 frame/s, significantly slower than the required rate. Furthermore a-Si FPIs provide low image quality at their fastest frame-rates and are susceptible to damage by the treatment beam, requiring replacement every 1-2 years. Emerging CMOS active pixel sensors use an addressable and partial read-out architecture to achieve significantly improved frame rates relative to their passive counterparts. They are also capable of superior resolution, image quality and radiation-hardness. This study investigates the feasibility of using a CMOS portal imager to quickly and accurately track radio-opaque markers during radiotherapy. A custom CMOS imaging system was designed and constructed in collaboration with the MI3 consortium. The performance of this system was characterised and compared with an a-Si FPI. Four cylindrical gold markers of diameter 0.8 to 2 mm and length 8 mm were positioned on a motion-platform and moved according to the Lujan approximation to respiratory motion. Images were acquired using the megavoltage treatment beam at a range of frame and dose rates. The success rate of an automatic detection routine, mean-error from the expected position and contrast-to-noise ratio of the marker imager were then evaluated as a function of marker size, marker speed and integration time. The CMOS imager was found to offer improved resolution and signal-to-noise over the standard a-Si FPI at comparable dose. The long integration time of the FPI resulted in marker images being too blurred to detect. The CMOS was able to detect all four markers >90% of the time and estimate their position to within 0.04 mm at 150 MU/min and 20 frame/s. However success rate declined with decreasing dose and increasing integration time. In conclusion a CMOS megavoltage imaging system was found to offer superior signal-noise and resolution than the standard a-Si FPI. Furthermore the high speed of CMOS provided sub mm tracking of moving markers at a clinically acceptable dose rate and marker size.

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