Asynchronization is what happens when two moving parts do not align as planned. Like when my mother wants a photograph of her five young grandchildren. Anyone who has experience with children knows it is next to impossible to get multiple versions of tiny, busy humans to sit still and look in the same general direction at the same time. As if that wasn’t challenging enough, my mother is not exactly technologically gifted. So there they sit (sort of), while grandma tries desperately to navigate digital photography. What we want is a perfectly framed portrait of five smiling children. What we get is grandma raising the camera to ask why they all have their tongues out, while simultaneously pushing the exposure button.

Moving target + moving source = asynchronization.
The MLC interplay effect with tumor motion is similar to the above example. **MLC interplay** can be defined as the combination of inherent tumor motion and planned movement of the MLC during IMRT treatment delivery. At any given time, the target may not be located exactly where it was relative to the MLC during planning, creating not only physical misalignment, but differences in tissue heterogeneity along the treatment path as well. The result of this effect can be **hot or cold spots in and around the target**. Despite our best efforts at immobilization, internal anatomy is in constant motion (much like children!). Radiation treatment plans are based off a snapshot of anatomy. We have very sophisticated imaging available (CT, MRI, PET, 4D imaging, MIPs, etc.), which makes it possible to predict normal organ motion, and how it affects the target. For instance, we can track lung tumor movement during deep inspiration and deep expiration to get an idea of the range of possible movement during treatment. We can design our treatment fields to encompass the entire area the PTV may occupy at any time, despite what the target might be doing...
What we cannot predict is where that tumor will be relative to the open area defined by the MLC at a given moment during an IMRT treatment. Ong et al stated that the MLC interplay effect has been reported as resulting in a dose variance of up to 18% in a single fraction.[1] The interplay effect results in a dose variance of only 1-2% if the treatments are spread over a 5-6 week fractionation. This is because natural feathering, or blurring, of the dose distribution will make up for any hot or cold spots created infrequently during treatment. The major concern is the effect of MLC interplay during stereotactic treatments, when PTVs are smaller, treatments are more conformal with smaller margins, and there are a limited number of fractions to get it right. In addition, Ehler et al reported an increase in the interplay effect with a high degree of MLC modulation.[2] However, they also made the case that, at least for lung SBRT, increased treatment time per field may actually reduce dose variation because the target will undergo several more breathing cycles, resulting in intra-fractional blurring.[2]

It has been shown that tumors located near the diaphragm can move up to 2cm during a breathing cycle.[2] Still, the effects of organ motion are not limited to the lung. Anatomic motion is an issue in every part of the body. Abdominal organs are subject to movement due to breathing and normal peristaltic activity. Sub-optimal immobilization can allow for voluntary movement of the head during brain treatments, and actions such as swallowing can affect anatomy in the neck and mediastinum. Pelvic targets can move as a result of changes in bladder or rectal filling and the presence of gas. Mutanga et al conducted a study to evaluate intrafractional motion of the prostate during IMRT. They obtained KV radiographs at several points during treatment each day, including at treatment conclusion, to evaluate the location of fiducial markers relative to the initial set-up position.[3] Below are images from their study demonstrating the extent of prostate movement:
In their study, Ong et al evaluated the effect of MLC interplay on RapidArc SBRT lung treatments, and found the dose variance to be negligible. They did report the MLC interplay effect to be more pronounced, resulting in 10% higher dose variance, if the MLC are constantly moving perpendicular or parallel to the plane of target movement (such as inferior–superior for lung and anterior–posterior for prostate). The effect was reduced in their particular study due to the RapidArc collimator being angled at 40–45 degrees during treatment. Ye et al performed a similar study evaluating the MLC interplay effect during IMRT and VMAT treatments to the prostate. They also found the dose variance to be negligible. The common recommendation is for solid, reproducible immobilization and patient education. Ehler et al also demonstrated decreased interplay effect when respiratory gating techniques are employed for lung treatments. Even though increased treatment times per field may create dose blurring, the fact remains that shorter treatment times will decrease the effect of MLC interplay on dose distribution, primarily by eliminating patient movement due to discomfort (or boredom).
Now hold still or else the radiation won't go where it is supposed to and will cause you a very slow and very painful death... Ha ha, I'm just with ya, but seriously, hold still now...

A Steady Diet of Bitterness, Sarcasm, and Hate

(a bit of crass therapist humor, no offense meant.)

References


