

Some new angles on the magic angle effect

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(what radiologists know and don't know about this)

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SCIENTIFIC ARTICLE



Some new angles on the magic angle: what MSK radiologists know and don't know about this phenomenon

Michael L. Richardson¹ · Behrang Amini² · Todd L. Richards¹

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Abstract

Purpose Magic angle effects (MAE) are well-recognized in musculoskeletal (MSK) MRI. With short TE acquisitions, the signal intensity of tendons, ligaments, and menisci depend on their orientation relative to the main magnetic field (B_0). An interactive resident physics teaching module simulating MR imaging of a tendon forced us to identify and correct several misconceptions we had about MAE. We suspected these misconceptions were shared by other MSK radiologists.

Materials and methods We surveyed members of the Society of Academic Bone Radiologists (SABR) regarding which pulse sequences, acquisition parameters, tissues and angles relative to B_0 were most likely to produce MAE.

Results Survey respondents knew that MAE strongly depend on TE and commonly appear on T1W, FSE and PD sequences, but were less aware that MAE may also appear on T2W, STIR and DWI sequences. They knew of MAE effects in tendons, ligaments and cartilage, but were less aware of those in entheses, peripheral nerves and intervertebral discs. Respondents underestimated the wide angular range (full-width at half-maximum $\approx 40^\circ$) over which significant MAE can be seen with short TE.

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Keywords MR physics · Magic angle effect · Musculoskeletal · Tendon imaging · Artifact

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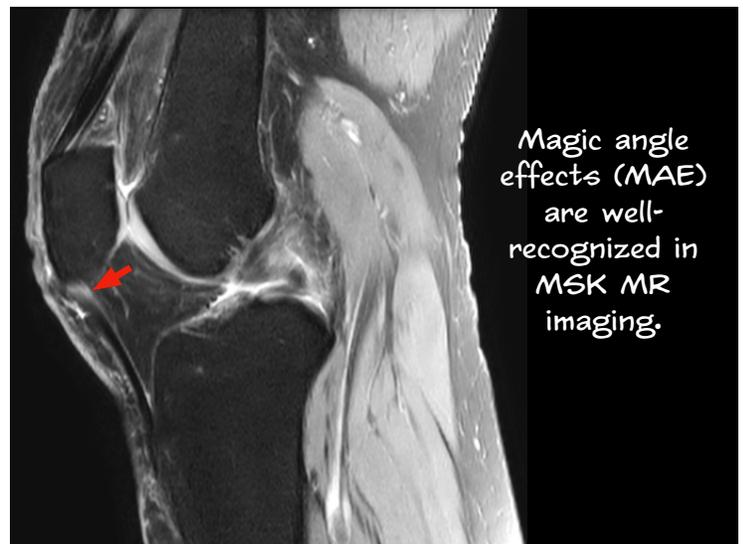
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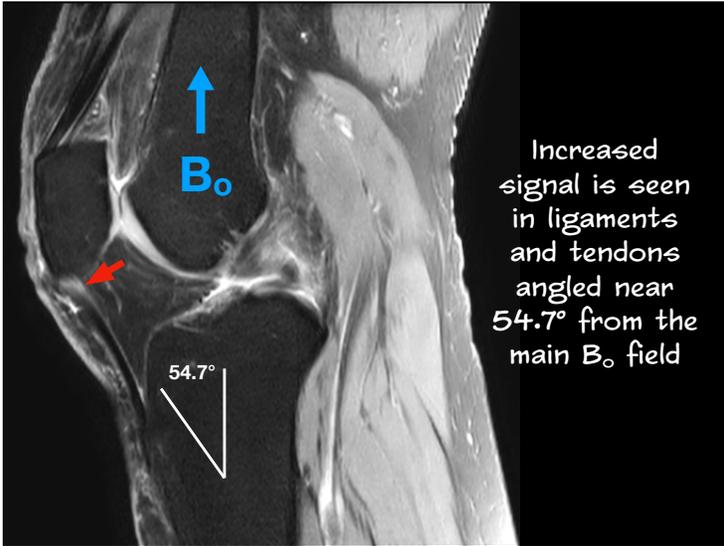
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Sadly, no one has tried to buy our souls during the course of this project...





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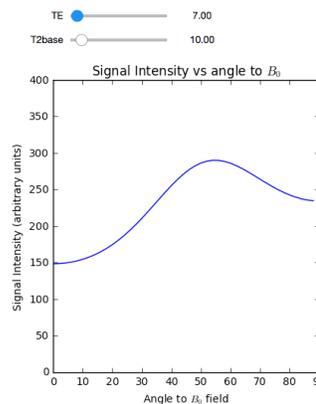
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$$3\cos^2\theta - 1 = 0$$

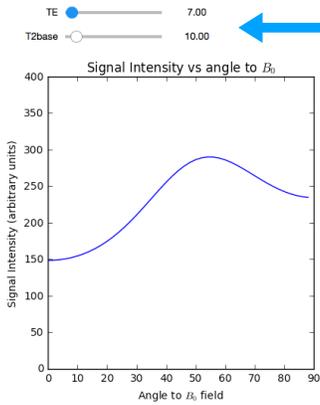
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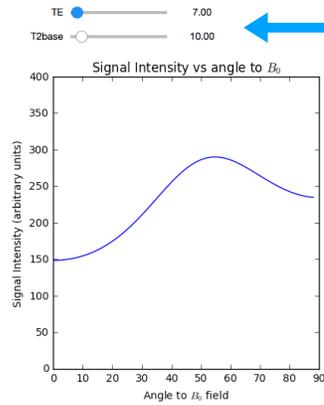
$$\theta \in \{54.7^\circ, 125.3^\circ, 234.7^\circ, 305.3^\circ\}$$



We created a computer-based simulator to teach our residents about magic angle effects.

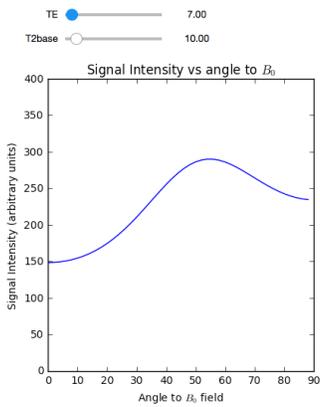


users can vary TE and tissue T2 with these sliders

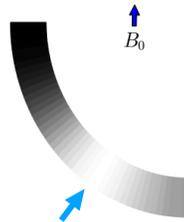


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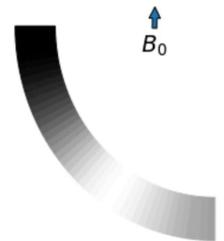
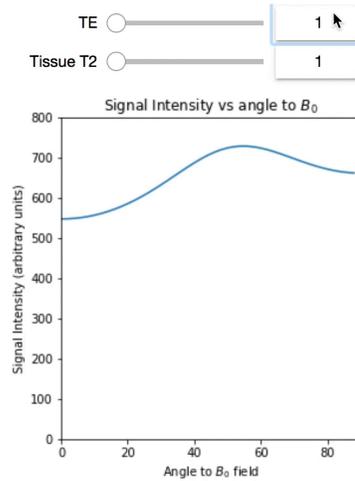
and immediately see changes in signal intensity as a function of angle to B_0



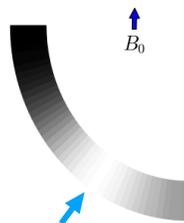
Magic Angle Simulator



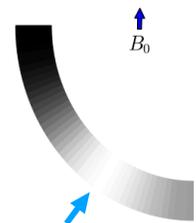
and also immediately see how this would look in a simulated ankle tendon



Magic Angle Simulator



Magic Angle Simulator



HOWEVER

the findings in our simulated tendon were *MUCH* more pronounced than we expected

after checking our math, we realized that we had to adjust our beliefs about MAE

we decided to survey other MSK radiologists to see if they shared our previous misconceptions about MAE



Survey population:

members of the Society of Academic Bone Radiologists (SABR)

+ 6 non-SABR fellows



Survey population:

31

replies



Survey questions:

4

questions posed on MAE



Please compare your own answers to everyone else's



T1-weighted

T2-weighted

Fast spin-echo

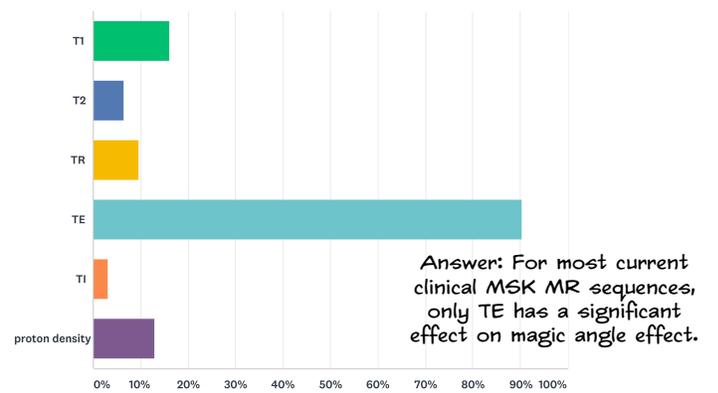
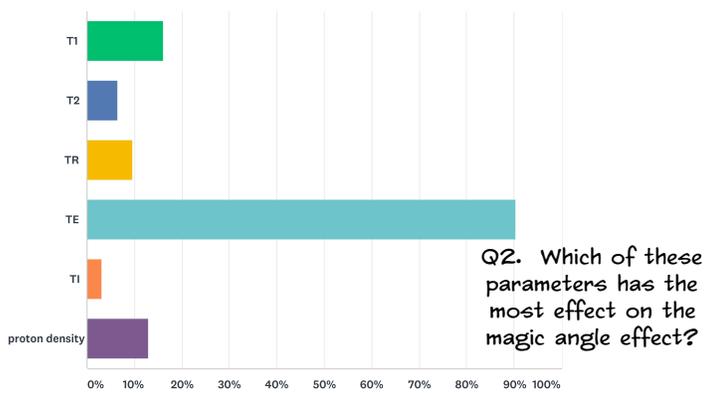
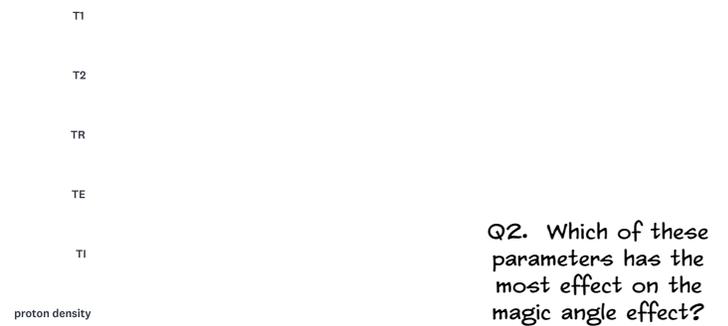
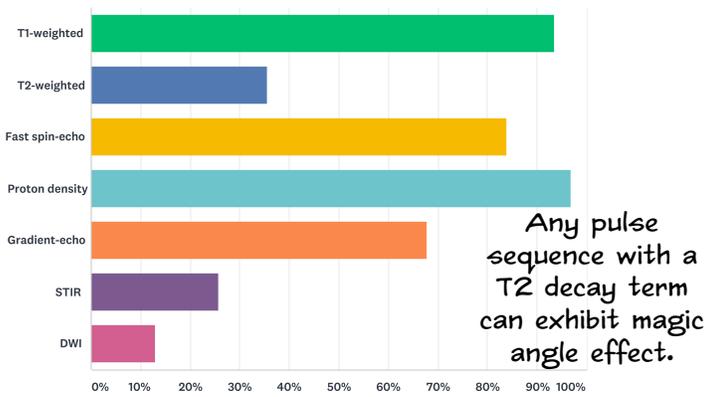
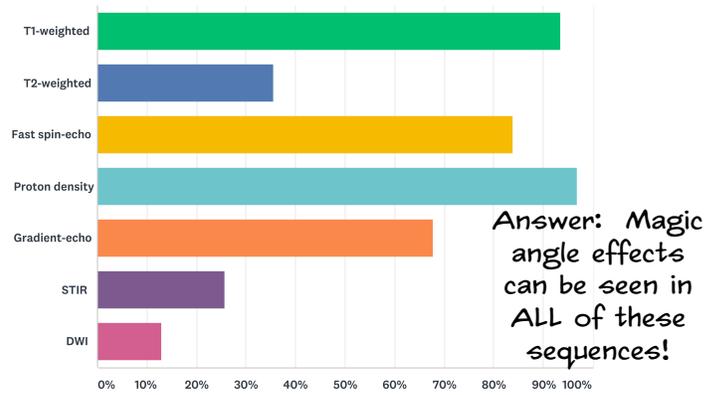
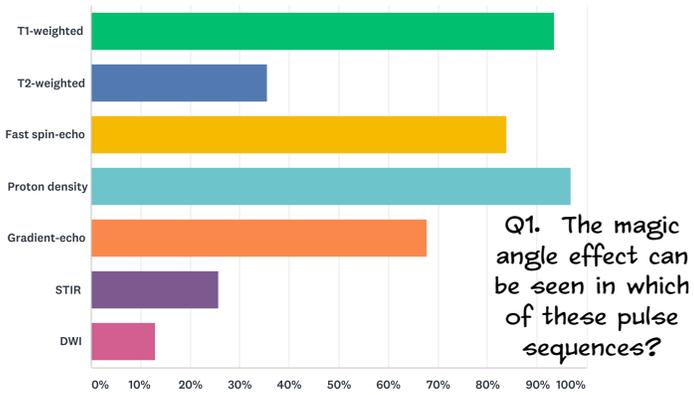
Proton density

Gradient-echo

STIR

DWI

Q1. The magic angle effect can be seen in which of these pulse sequences?



$$S(\theta) = S_1 + S_0 \cdot e^{-TE[\frac{1}{T_{2base}} + \frac{1}{a(3\cos^2\theta - 1)^2}]} \cdot e^{-\beta(TE - t_0)}$$

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Definitely changes with angle to B_0

$$S(\theta) = S_1 + S_0 \cdot e^{-TE[\frac{1}{T_{2base}} + \frac{1}{a(3\cos^2\theta - 1)^2}]} \cdot e^{-\beta(TE - t_0)}$$

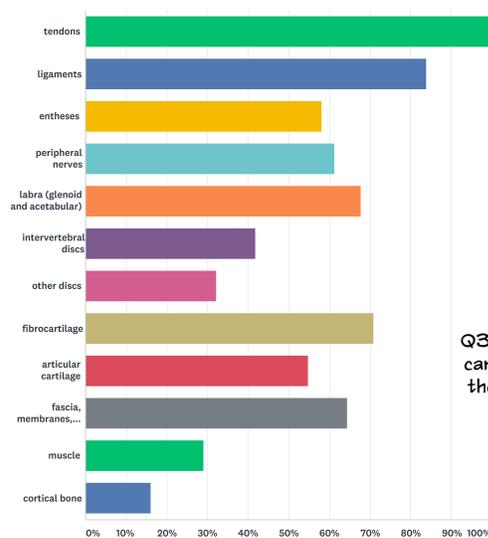
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T2 term usually swamped by TE term

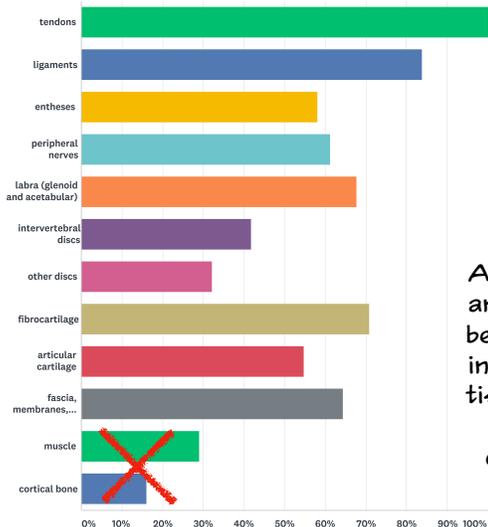
otherwise, it's just TE



Q3. Magic angle effect can be seen in which of these MSK tissues or structures?



Q3. Magic angle effect can be seen in which of these MSK tissues or structures?



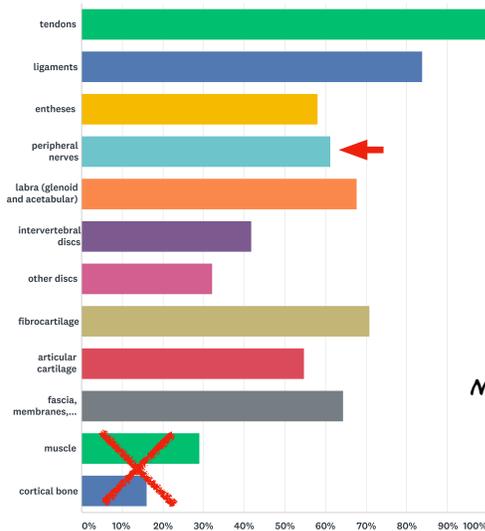
Answer: Magic angle effect can be seen clinically in ALL of these tissues EXCEPT muscle and cortical bone.



lots of parallel collagen in these tissues



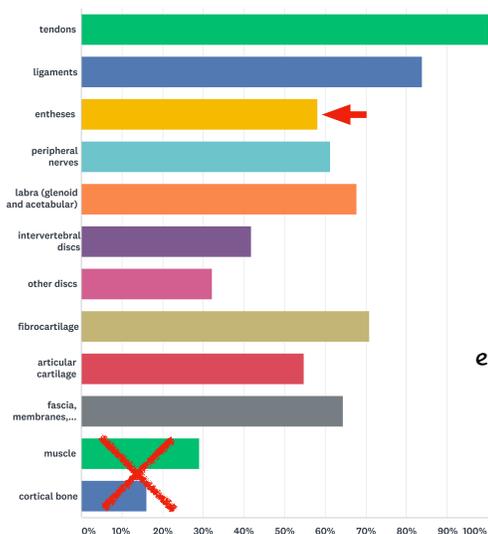
lots of parallel collagen in peripheral nerves



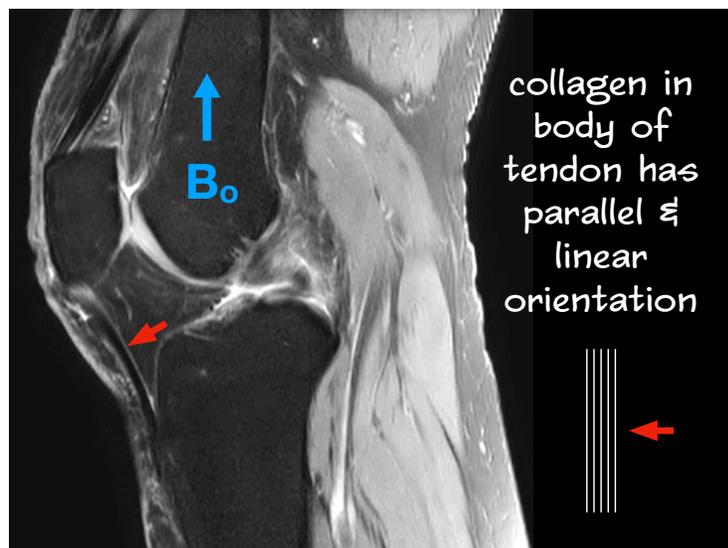
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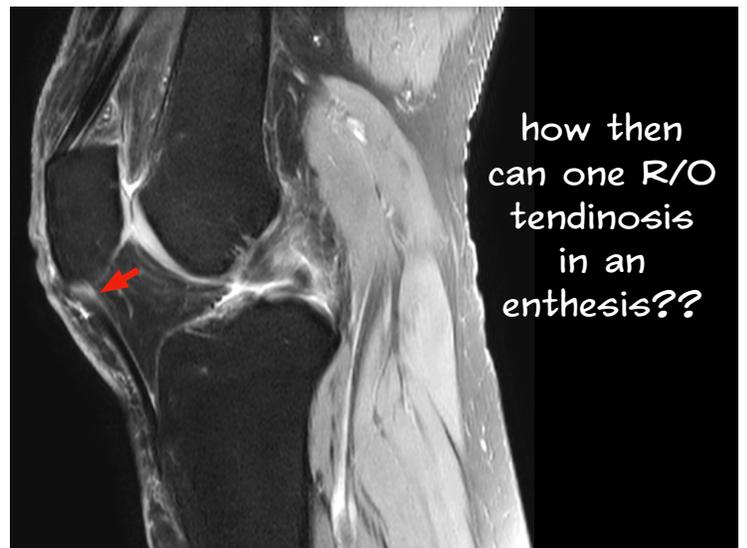
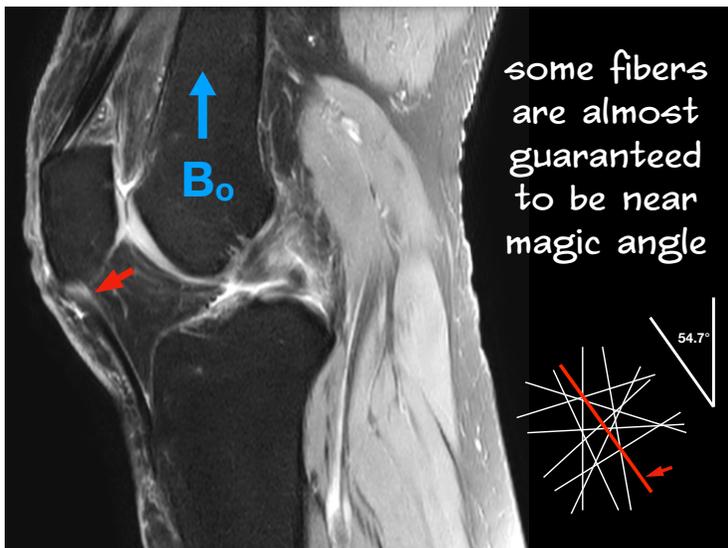
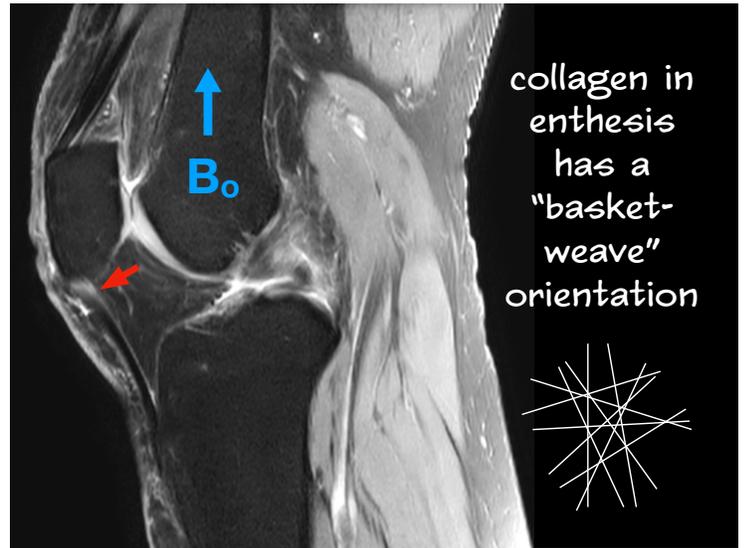
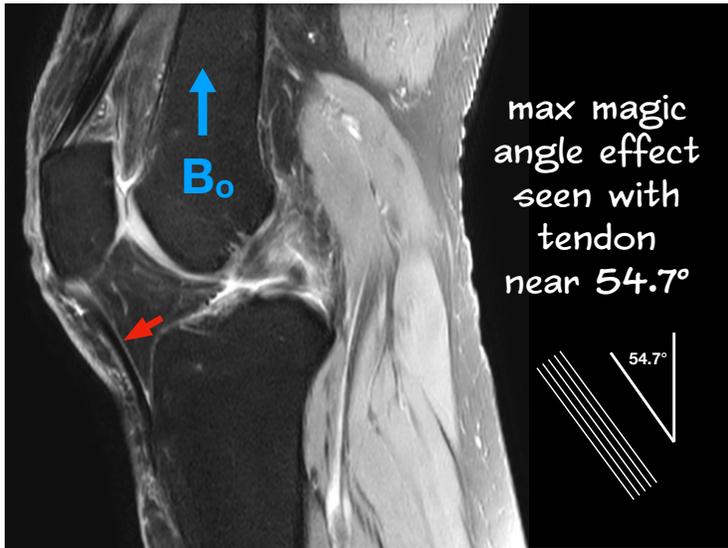


MAE in peripheral nerves may exceed that in tendons



entheses are a special case



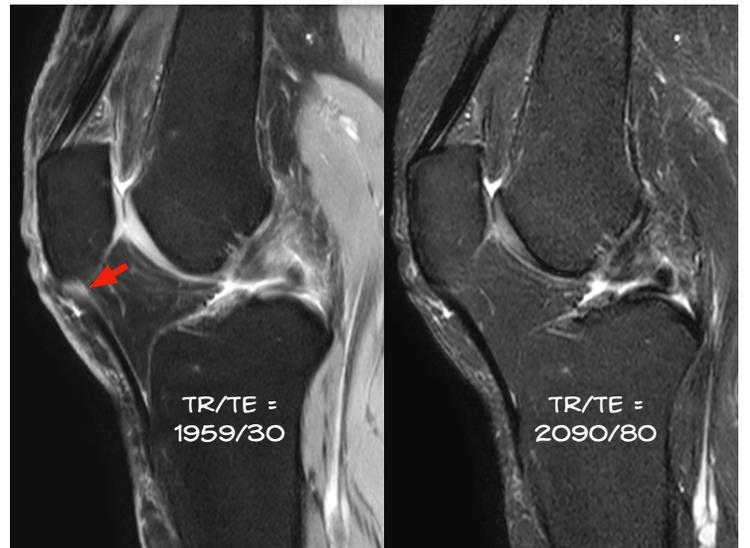
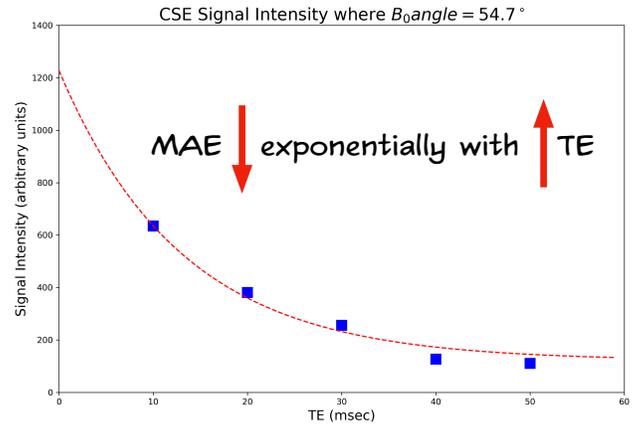
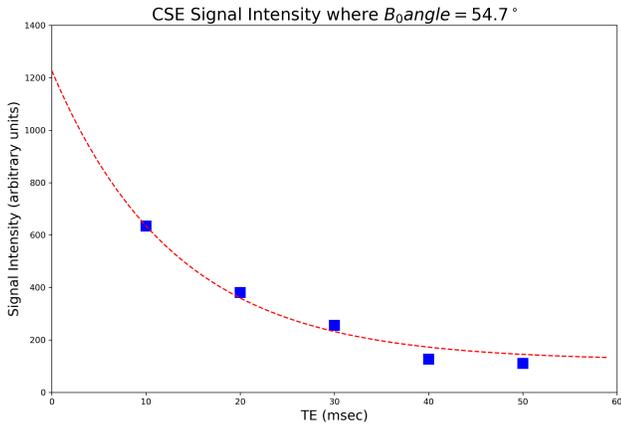


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just at 55°

50 - 60°

45 - 65°

40 - 70°

35 - 75°

30 - 80°

Q4. Over what range of angles can one expect to see significant magic angle effect?

just at 55°

50 - 60°

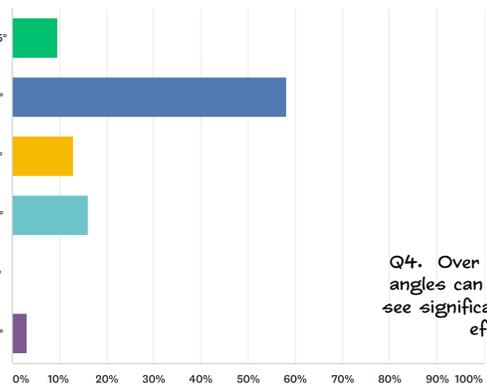
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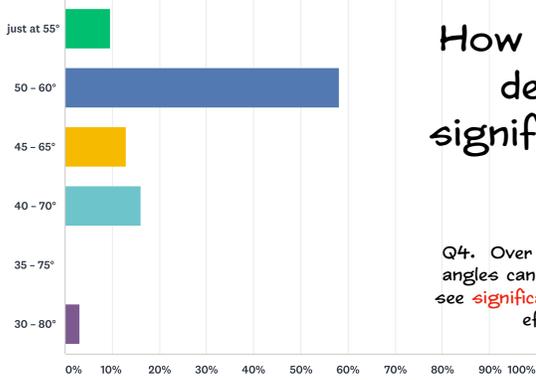
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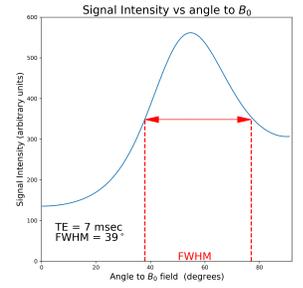
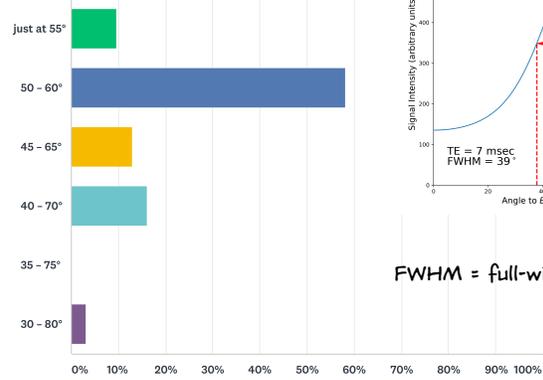
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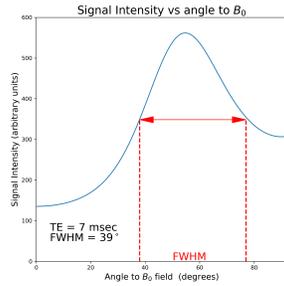
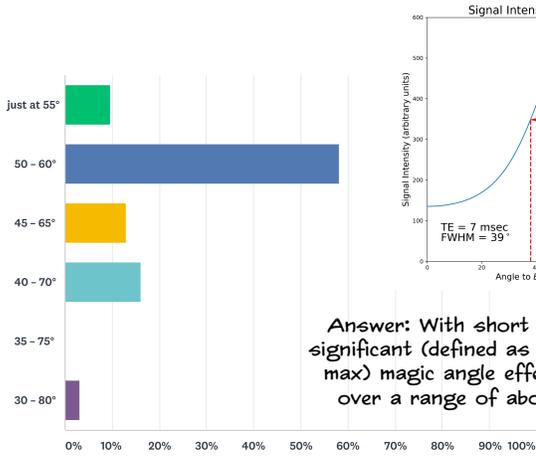


How do you define significant???

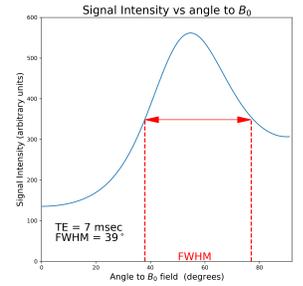
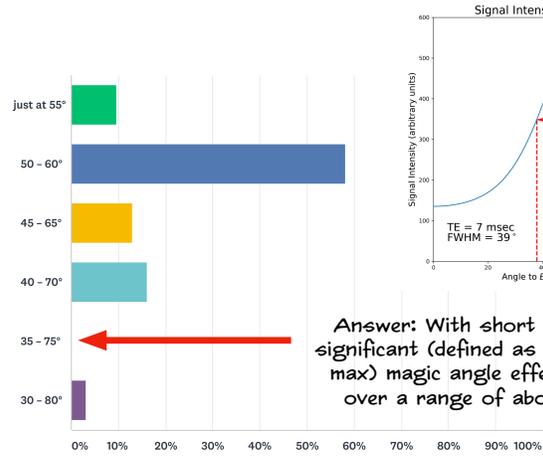
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FWHM = full-width at half max



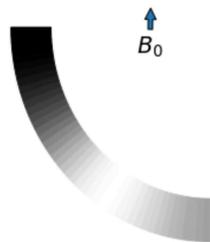
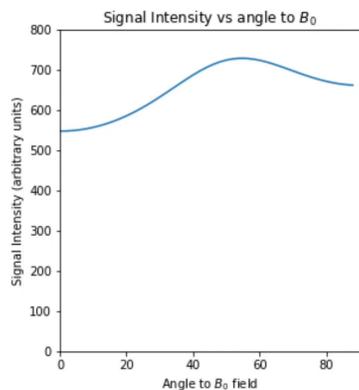
Answer: With short TE (~7 msec), significant (defined as full-width at half max) magic angle effect can be seen over a range of about 35° - 75°.



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TE

Tissue T2



CONCLUSION

MSK radiologists tend to underestimate the variety of situations in which significant magic angle effects may be seen.



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<http://uwmsk.org/jupyter/>

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using the free, open-source, Jupyter
scientific notebook system.

Feel free to download this and our other
radiology notebooks at:

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