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PICTORIAL REVIEW

Diagnosis of typical and atypical transition zone prostate cancer and its mimics at multiparametric prostate MRI

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ABSTRACT

Many of the current clinical screening methods for prostate cancer (PCa) such as prostate-specific antigen (PSA) testing or transrectal ultrasound-guided prostate biopsy lack sensitivity and specificity for diagnosis of PCa of the transition zone (TZ). Recent technical advances in multiparametric-MRI have markedly improved detection of PCa of the TZ. However, there are many diagnostic challenges that we still encounter in our daily practice that compromise the accuracy of the diagnosis. By performing both MRI-guided and ultrasound/MRI fusion-guided biopsies, we have gained extensive experience in the diagnosis of PCa of the TZ. Biopsy-proven examples including but not limited to typical and atypical PCa of the TZ as well as a wide variety of its mimics will be presented. Recognition of the MR features of typical and atypical PCa of the TZ and its mimics on multiparametric-MRI along with findings that help to differentiate these mimics from PCa is important in establishing an accurate diagnosis and in guiding clinical management.

INTRODUCTION

TZ tumours are estimated to account for approximately 30% of prostate cancer (PCa) and substantially contribute to morbidity and mortality from PCa because of the difficulty of their detection even though recent advances in multiparametric-MRI (mp-MRI) have significantly improved detection of PCa of the TZ.¹ Part of this difficulty is related to the TZ being composed of two histologically distinct types of tissue: glandular tissue which is hyperintense on T_2 weighted imaging (T2WI) and stromal tissue which is hypointense on T2WI mimicking TZ cancer.² In addition, a wide variety of atypical imaging presentations of TZ PCa as well as other anatomical and pathological processes in the TZ that mimic PCa on mp-MRI create diagnostic challenges. These mimics include but are not limited to chronic prostatitis, benign prostatic hyperplastic nodules, displaced central zone, anterior fibromuscular stroma and surgical capsule.³ MRI pearls and pitfalls in the diagnosis of typical and atypical TZ PCa and its mimics will be emphasized in this pictorial essay.

TYPICAL TRANSITION ZONE CANCER

PCa of the TZ is more challenging to detect and diagnose because the MR signal intensity characteristics of the

normal TZ and carcinoma often overlap.⁴ The key histological features of TZ PCa pertinent to MRI are increased cellular density, decreased luminal volume, reduced extracellular space and neoangiogenesis. Mp-MRI of the prostate incorporates anatomical and functional techniques that are capable of correlating histological changes of PCa with MRI features. According to the PI-RADS™ v. 2 document, T2WI is the most useful sequence in the diagnosis of TZ PCa, followed by diffusion-weighted imaging (DWI)/apparent diffusion coefficient (ADC) map and then dynamic contrast-enhanced (DCE) imaging.⁵ On T2WI, PCa of the TZ typically appears as focal, homogeneous hypointensity against a background of the high-signal-intensity glandular tissue with ill-defined margins (“erased charcoal sign”), lenticular shape, the absence of a capsule and invasion of the anterior fibromuscular stroma (Figure 1a).^{4,5} DWI detects abnormal tissue properties in PCa such as increased cellular density and membrane permeability. Therefore, TZ PCa appears hyperintense on DWI and hypointense on ADC maps, indicating restricted diffusion (Figure 1b,c). It is common that diffusion restriction of TZ PCa may be only identified on the ADC map or DWI not on both if b -value is ≤ 1000 (based on

Figure 1. Prostate cancer (PCa) in the right transition zone (TZ) in a patient with elevated prostate-specific antigen of 23 and 5 prior negative transrectal ultrasound-guided prostate biopsies. (a) Axial T_2 weighted imaging shows a homogeneous, hypointense mass (arrows) with indistinct margins at the anterior aspect of right TZ resulting in asymmetric contour (curved arrow). (b) Diffusion-weighted imaging ($b=1000$) shows severe diffusion restriction of the mass (arrows). (c) Apparent diffusion coefficient (ADC) map demonstrates severe diffusion restriction of the mass (arrows). (d) Dynamic contrast-enhanced imaging shows contrast washin and washout of the mass (arrows). MRI-guided biopsy confirmed PCa, Gleason Score 9.

our experience), particularly for those PCa Gleason Scores 6 or 7 (3 + 4). If higher b -values such as $b \geq 1600$ resulting in sufficient signal are used, those PCa Gleason Scores 6 or 7 likely

will be identified on the ADC map and DWI. A correlation between lower ADC values and higher Gleason scores of PCa has been reported by many published studies.⁵⁻⁷

Table 1. Typical MR features of prostate cancer (PCa) of the transition zone (TZ) at multiparametric-MRI

TZ PCa	Typical MR features
T_2 weighted imaging	Focal, homogeneous hypointensity against a background of high signal intensity glandular tissue
	Ill-defined margins
	Lenticular shape
	Absence of a capsule
	Invasion of the anterior fibromuscular stroma
DWI	Hyperintensity on DWI, hypointensity on ADC maps with lower ADC values correlating with higher Gleason scores of PCa
Dynamic contrast-enhanced imaging	Early and rapid enhancement, earlier and stronger than that of the rest prostate
	Subsequent contrast washout or plateau

ADC, apparent diffusion coefficient; DWI, diffusion-weighted imaging.

Table 2. Atypical MR features of prostate cancer (PCa) of transitional zone at multiparametric-MRI

Atypical MR features of TZ PCa	Key MR clues in diagnosis
Well-defined margins	Featureless appearance (“erased charcoal sign”)
	Severe diffusion restriction on DWI and ADC map
	Abnormal early enhancement with washout
	Possible presence of partially irregular margins
T_2 inhomogeneity or hyperintensity	Ill-defined margins
	Diffusion restriction on DWI and ADC map
	Abnormal early enhancement with washout
Atypical features on DWI and ADC	Convincing abnormality on T2WI despite diffusion restriction that may be only present either on ADC map or DWI but not on both
Lack of rapid contrast washin and washout	Not necessary for but increases confidence in the diagnosis of PCa
	Typical features on T2WI and DWI despite lack of abnormal enhancement

ADC, apparent diffusion coefficient; DWI, diffusion-weighted imaging; T2WI, T_2 weighted imaging; TZ, transition zone.

Although there are still no definite ADC cut-off values recommended for the differentiation between PCa and normal prostate tissue, the range of ADC values from 800 to 850 is the most useful cut-off.^{6,7} Because tumour neovessels in TZ PCa are highly irregular and tortuous with increased permeability, early and rapid contrast enhancement (earlier and stronger than that of the rest of the prostate) and subsequent contrast washout or plateau is expected to be observed in PCa (Figure 1d).⁵ A typical PCa of the TZ presents with MRI abnormalities on T2WI, diffusion restriction on DWI and/or ADC map, and rapid contrast washin and washout on DCE imaging (Figure 1) (Table 1).

ATYPICAL TRANSITION ZONE CANCER

It is common to have a PCa of the TZ present with atypical MRI features. Specifically, focal, homogeneous T_2 -hypointensity and irregular margins are characteristic features of TZ PCa, but these features are only present in 51% and 58% of TZ tumours, respectively.⁸ Therefore, in order to achieve high accuracy in the diagnosis of PCa, radiologists must be familiar

with the atypical MRI features of TZ PCa. The following are several common but atypical presentations of TZ PCa encountered frequently (Table 2).

Well-defined margins of prostate cancer of the transition zone

As mentioned above, ill-defined margins are only present in 58% of TZ PCa. The margins of the remaining TZ PCa may be not identified or may be pseudo well defined, mimicking a benign hypertrophic nodule (Figure 2).⁸ The aetiology of the pseudo-well-defined margins is unclear but may be due to compression of the surrounding normal prostate tissue. Imaging clues that allow for accurate diagnosis of PCa in such cases include a featureless appearance of the lesion (“erased charcoal sign,” Figure 2a), severe diffusion restriction on both DWI and ADC map (Figure 2b,c) and abnormal early enhancement with washout (Figure 2d). Sometimes, partially irregular margins of the lesion may be detected on T2WI and/or ADC map. If PCa of the TZ still cannot be excluded after analyzing all imaging features of a well-defined nodule, we recommend imaging-guided

Figure 2. Prostate cancer (PCa) with well-defined margins in the left transition zone (TZ) in a patient with elevated prostate-specific antigen of 5.9. (a) Axial T_2 weighted imaging shows a homogeneous, hypointense mass (arrow) with pseudocapsule (arrowheads) in the left TZ mimicking a benign nodule. (b) Apparent diffusion coefficient map shows severe diffusion restriction of the mass (arrow). (c) Dynamic contrast-enhanced imaging shows rapid contrast washin and washout of the mass (arrow). MRI/ultrasound fusion-guided biopsy confirmed PCa, Gleason Score 9.

Figure 3. Prostate cancer (PCa) with T_2 hyperintensity in the right apex transition zone (TZ) in a patient with an elevated prostate-specific antigen of 7.2 and 2 prior negative transrectal ultrasound-guided biopsies. (a) Axial T_2 weighted imaging shows a homogeneous mass (arrows) at the right apex TZ with T_2 hyperintensity relative to that of the left apex TZ. (b) Apparent diffusion coefficient map shows diffusion restriction of the mass (arrows). MRI/ultrasound fusion-guided biopsy confirmed PCa, Gleason Score 7.

biopsy of the nodule to exclude potentially aggressive tumour (Figure 2).

T_2 inhomogeneity or hyperintensity of prostate cancer of the transition zone

Unfortunately, TZ PCa presents with homogeneous hypointensity on T2WI in only 51% of cases. A variety of factors may cause TZ PCa to present with different signal intensity on T2WI. TZ PCa may be T_2 -hyperintense due to oedema or mucin (Figure 3) or partially inhomogeneous if mixed with or arising within benign prostatic hyperplastic nodules (Figure 4).⁸ In these situations, diagnosis of TZ PCa may be very difficult. If a lesion demonstrates most of the typical MRI features of TZ

PCa (ill-defined margins, diffusion restriction and abnormal enhancement) but atypical T_2 signal intensity (slightly high or inhomogeneous, Figures 3 and 4), the lesion should be considered suspicious for tumour and biopsy of the lesion is warranted (Tables 2 and 3).

Diffusion restriction only present either on ADC map or DWI but not on both

T2WI is the dominant sequence for diagnosis of PCa of the TZ.⁵ If the abnormality is only identified on T2WI without associated diffusion restriction, PCa of the TZ is often not present. In other words, diffusion restriction of a suspicious lesion is often necessary to make the diagnosis of PCa of the TZ (Figure 5).

Figure 4. Prostate cancer (PCa) arising from a hypertrophic nodule in a patient with an elevated prostate-specific antigen of 8.9. (a) Axial T_2 weighted imaging shows a homogeneously hypointense mass (arrow) with ill-defined margins arising from the anterior aspect of a well-defined nodule (curved arrow). (b) Apparent diffusion coefficient map shows diffusion restriction of the mass with irregular border (arrow) as well as the well-defined nodule (curved arrow). MRI/ultrasound fusion-guided biopsy confirmed PCa Gleason Score 7, anterior aspect of a benign nodule.

Table 3. Key MR clues that help differentiate mimics from prostate cancer (PCa) of the transition zone (TZ)

Mimics of TZ PCa	Key clues in differentiation
Chronic prostatitis	Geographic appearance of the T_2 hypointensity without associated mass effect or contour deformity
	Mild diffusion restriction on DWI and ADC map
	Relatively mild abnormal enhancement on DCE
Hypertrophic stromal nodule	Round or oval shape
	Well-defined margins
	T_2 hypointense capsule
	T_2 hypointensity, sometimes lower than that typically expected for PCa
	Possible presence of small internal foci of T_2 hyperintensity
	Mild diffusion restriction or diffusion restriction which may be only seen either on ADC map or DWI
Normal displaced central zone	Enhancement similar to the other benign nodules in the prostate rather than earlier and stronger than the rest of the prostate
	Well-defined margins
	Symmetry or near symmetry on all sequences
	Classic location at the level of the ejaculatory ducts
Anterior fibromuscular stroma	Lack of abnormal early enhancement with washout
	Significant T_2 hypointensity, lower than that typically expected for PCa
	Lack of abnormal early enhancement with washout
	Continuity with the rest of the anterior fibromuscular stroma
Thickened surgical capsule	Midline or near midline location
	Classic location of the surgical capsule between the TZ and PZ
	Band-like or elongated shape
	Lack of abnormal early enhancement with washout

ADC, apparent diffusion coefficient; DCE, dynamic contrast-enhanced imaging; DWI, diffusion-weighted imaging; PZ, peripheral zone.

However, diffusion restriction of the lesion may be only present either on ADC map or DWI but not on both. The diagnosis of PCa of the TZ can still be made if the abnormality on T2WI is convincing (Figure 6).

Lack of rapid contrast washin and washout
Lack of a rapid contrast washin and washout of a lesion in TZ PCa on DCE imaging is not uncommon.⁸ Sometimes, no enhancement of the TZ PCa is identified due to low grade, small

Figure 5. Stromal nodule mimicking prostate cancer (PCa) in a patient with an elevated prostate-specific antigen of 25. (a) Axial T_2 weighted imaging (T2WI) shows a homogeneous, hypointense lesion (arrow) with ill-defined margins in the right transition zone. (b) Dynamic contrast-enhanced imaging shows rapid contrast washin and washout of the nodule (arrow), mimicking PCa. (c) Apparent diffusion coefficient map shows only mild diffusion restriction of the nodule (arrow), and diffusion-weighted imaging is normal (not shown). MRI/ultrasound fusion-guided biopsy confirmed benignity.

Figure 6. Prostate cancer (PCa) only seen on T_2 and apparent diffusion coefficient (ADC) map in a patient with an elevated prostate-specific antigen of 7.5. (a) Axial T_2 weighted imaging (T2WI) shows a homogeneous, hypointense lesion (arrow) with ill-defined margins in the left transition zone. (b) ADC map shows diffusion restriction of the lesion (arrow). (c) Diffusion-weighted imaging ($b = 1000$) shows normal appearance of the lesion (arrow), and no enhancement was identified on dynamic contrast-enhanced imaging (not shown). MRI/ultrasound fusion-guided biopsy confirmed PCa, Gleason Score 7.

size or necrosis of the tumour. Rapid enhancement with wash-out is not a necessary MR feature for the diagnosis of TZ PCa, but the presence of this feature does increase confidence in the diagnosis.⁵ That is, if a lesion has typical MRI features of TZ PCa at T2WI and DWI, the lesion should be considered suspicious for tumour, regardless of whether it has rapid enhancement with washout.

MR FEATURES OF MIMICS OF PROSTATE CANCER OF THE TRANSITION ZONE

Chronic prostatitis

As in the peripheral zone (PZ), chronic prostatitis is not uncommon in the TZ. Chronic prostatitis in the TZ may present as diffuse or focal T_2 hypointensity with diffusion restriction and abnormal enhancement due to increased inflammatory cellular infiltrates, thus mimicking PCa (Figure 7).³ Key clues for differentiation of chronic prostatitis from PCa include geographic appearance of the T_2 hypointensity without associated mass effect or contour deformity (Figure 7a), mild diffusion

restriction on DWI and ADC map (Figure 7b) and relatively mild abnormal enhancement on DCE imaging.³

Hypertrophic nodules in the transition zone

Hypertrophic nodules are present in the TZ in the majority of patients undergoing prostate MRI. These nodules may be hypo-, iso- or hyperintense relative to the normal TZ on T_2 weighted images depending on the ratio of glandular to stromal tissue. Mixed and stromal nodules can demonstrate T_2 hypointensity due to the presence of prominent sclerotic, fibrous or muscular elements. These nodules may also demonstrate low ADC values and rapid contrast washin and washout, mimicking PCa (Figure 8).⁸ Key clues for differentiation of a stromal nodule from PCa on T2WI include a well-defined contour (Figure 8a), signal intensity that can be lower than that typically expected for PCa and possible presence of small internal foci of T_2 hyperintensity secondary to mixing with minimal glandular tissue. Diffusion restriction of a stromal nodule may be mild or only seen either on ADC map or DWI. On DCE imaging,

Figure 7. Prostatitis mimicking prostate cancer in the right transition zone (TZ) in a patient with elevated prostate-specific antigen of 6.8. (a) Axial T_2 weighted imaging shows an ill-defined hypointense area in the right TZ (arrow) at the mid gland. (b) Apparent diffusion coefficient (ADC) map shows the area with mildly low ADC value (arrow). MRI/ultrasound fusion-guided biopsy confirmed inflammation.

Figure 8. Hypertrophic nodule in the right transition zone (TZ) mimicking prostate cancer in a patient with elevated prostate-specific antigen of 9.3. (a) Axial T_2 weighted imaging shows a hypointense nodule with well-defined margins in the right TZ (arrows). (b) Diffusion-weighted imaging ($b=1000$) shows associated diffusion restriction of the nodule (arrows). (c) Dynamic contrast-enhanced imaging demonstrates rapid contrast washin and washout of the area (arrows). Curved arrow indicates similar enhancement in the left TZ. MRI/ultrasound-fusion guided biopsy of the nodule confirmed benignity.

enhancement of a stromal nodule may be similar to the other benign nodules in the prostate (Figure 8c).

Normal displaced central zone

The central zone is a layer of tissue that surrounds the ejaculatory ducts from the level of the prostatic base down to the verumontanum. When the TZ is enlarged, the central zone may be displaced to the base of the prostate, overlapping the TZ. Compared with the PZ, the central zone has histological features more akin to those of the ejaculatory ducts and seminal vesicles, suggesting it is a Wolffian duct derivative.⁹ Therefore, the central zone has denser stroma which results in homogeneous T_2 hypointensity and low ADC values mimicking PCa (Figure 9),

particularly when the sides of the central zone are asymmetric (seen in 20% of patients).^{8,10} Key clues for differentiation of the displaced central zone from PCa include well-defined margins, symmetry or near symmetry on all sequences, classic location at the level of the ejaculatory ducts and lack of rapid enhancement with washout.

Anterior fibromuscular stroma

The anterior fibromuscular stroma is a band of fibromuscular tissue in the anterior aspect of the prostate. Histologically, it is comprised of dense, irregular connective tissue with a large number of smooth muscle fibres interposed with adjacent skeletal muscle fibres of the urethra. The anterior fibromuscular

Figure 9. Displaced central zone in the right base transition zone (TZ) mimicking prostate cancer in a patient with elevated prostate-specific antigen of 5.6 and prior negative transrectal ultrasound-guided biopsies. (a) Axial T_2 weighted imaging shows a hypointense area in the right base TZ (long arrow) laterally at the level of the ejaculatory ducts (short arrows). (b) Apparent diffusion coefficient (ADC) map shows the area with low ADC value (arrow). Dynamic contrast-enhanced imaging shows no abnormal enhancement in the area (not shown). MRI/ultrasound-fusion guided biopsy confirmed normal prostate tissue.

Figure 10. Asymmetric and hypertrophic anterior fibromuscular stroma mimicking prostate cancer in a patient with elevated prostate-specific antigen of 12.8. (a) Axial T_2 weighted imaging (T2WI) demonstrates a markedly hypointense soft-tissue mass in the right anterior aspect of the transition zone (TZ) (arrow) displaced off the midline by the hypertrophic left TZ prostate (P). (b) Sagittal T2WI demonstrates the markedly hypointense soft-tissue mass (arrows) continuous with the anterior fibromuscular stroma (arrowheads). Bladder (B) and prostate (P) are noted. (c) Apparent diffusion coefficient map shows diffusion restriction of the mass (arrow). Dynamic contrast-enhanced imaging shows no abnormal enhancement of the mass (not shown). MRI/ultrasound fusion-guided biopsy confirmed benign fibromuscular stroma.

stroma has marked T_2 hypointensity and low ADC values due to its compact muscular and fibrous composition.¹¹ When asymmetry of the stroma occurs with a bulky appearance, it may mimic PCa (Figure 10). Key clues for differentiation of the anterior fibromuscular stroma from PCa include significant T_2 hypointensity (lower than that typical of PCa), lack of rapid enhancement with washout, continuity with the rest of the anterior fibromuscular stroma and midline or near midline location.

Thickened surgical capsule

In addition to the anatomical capsule of the prostate that surrounds the PZ, a “surgical” capsule surrounding the TZ has also been described as it provides a landmark for surgery of benign prostatic hypertrophy. This structure is composed of fibrous and muscular tissue.¹² A normal surgical capsule has hypointensity on both T_2 weighted images and ADC maps due to the densely

compacted fibromuscular tissue. It may mimic a small tumour that is growing within the confines of the lateral aspect of the TZ (Figure 11). However, the classic location of the surgical capsule (between the TZ and PZ) with a band-like or elongated shape helps to differentiate it from PCa.^{12,13} Furthermore, there is no rapid contrast enhancement with washout on DCE images as the capsule is comprised of fibromuscular tissue.

CONCLUSION

Difficulty in achieving high accuracy in the diagnosis of PCa of the TZ is well known due to the described stromal tissue in the TZ and atypical presentations of TZ PCa as well as its mimics (Table 3). Knowledge of and attention to the MRI features of typical and atypical TZ PCa and its mimics allows for definitive diagnosis or narrowed differential diagnosis. Accurate diagnosis is important for clinical management and helps avoid unnecessary intervention.

Figure 11. Thickened left surgical capsule mimicking prostate cancer in a patient with elevated prostate-specific antigen of 8. (a) Axial T_2 weighted imaging shows a hypointensity with band-like appearance between the left transitional and peripheral zones (arrow). (b) Apparent diffusion coefficient (ADC) map shows low ADC value of the region (arrow). Dynamic contrast-enhanced imaging shows no enhancement of the region (not shown). MRI/ultrasound fusion-guided biopsy confirmed benign prostatic tissue.

REFERENCES

1. Haas GP, Sakr WA. Epidemiology of prostate cancer. *CA Cancer J Clin* 1997; **47**: 273–87.
2. Ishida J, Sugimura K, Okizuka H. Benign prostatic hyperplasia: value of MR imaging for determining histologic type. *Radiology* 1994; **190**: 329–31. doi: <https://doi.org/10.1148/radiology.190.2.7506836>
3. Kitzing YX, Prando A, Varol C, Karczmar GS, Maclean F, Oto A. Benign conditions that mimic prostate carcinoma: MR imaging features with histopathologic correlation. *Radiographics* 2016; **36**: 162–75. doi: <https://doi.org/10.1148/rg.2016150030>
4. Akin O, Sala E, Moskowitz CS. Transition zone prostate cancers: features, detection, localization, and staging at endorectal MR imaging. *Radiology* 2006; **239**: 784–92. doi: <https://doi.org/10.1148/radiol.2392050949>
5. American College of Radiology. MR prostate imaging reporting and data system version 2.0, 2015 [Cited 20 July 2015]. Available from: <http://www.acr.org/Quality-Safety/Resources/PIRADS/>
6. Nagarajan R, Margolis D, Raman S. Correlation of Gleason scores with diffusion-weighted imaging findings of prostate cancer. *Adv Urol* 2012; **2**: 374805.
7. Bittencourt LK, Barentsz JO, de Miranda LC, Gasparetto EL. Prostate MRI: diffusion-weighted imaging at 1.5T correlates better with prostatectomy Gleason grades than TRUS-guided biopsies in peripheral zone tumours. *Eur Radiol* 2012; **22**: 468–75. doi: <https://doi.org/10.1007/s00330-011-2269-1>
8. Li H, Sugimura K, Kaji Y. Conventional MRI capabilities in the diagnosis of prostate cancer in the transition zone. *AJR Am J Roentgenol* 2006; **186**: 729–42. doi: <https://doi.org/10.2214/AJR.04.0775>
9. Quick CM, Gokden N, Sangoi AR, Brooks JD, McKenney JK. The distribution of PAX-2 immunoreactivity in the prostate gland, seminal vesicle, and ejaculatory duct: comparison with prostatic adenocarcinoma and discussion of prostatic zonal embryogenesis. *Hum Pathol* 2010; **41**: 1145–9.
10. Vargas HA, Akin O, Franiel T, Goldman DA, Udo K, Touijer KA, et al. Normal central zone of the prostate and central zone involvement by prostate cancer: clinical and MR imaging implications. *Radiology* 2012; **262**: 894–902. doi: <https://doi.org/10.1148/radiol.11110663>
11. Hricak H, Dooks GC, McNeal JE, Mark AS, Marotti M, Avallone A, et al. MR imaging of the prostate gland: normal anatomy. *AJR Am J Roentgenol* 1987; **148**: 51–8. doi: <https://doi.org/10.2214/ajr.148.1.51>
12. Semple JE. Surgical capsule of the benign enlargement of the prostate: its development and action. *Br Med J* 1963; **1**: 1640–3.
13. Rosenkrantz AB, Taneja SS. Radiologist, be aware: ten pitfalls that confound the interpretation of multiparametric prostate MRI. *AJR Am J Roentgenol* 2014; **202**: 109–20. doi: <https://doi.org/10.2214/AJR.13.10699>