Article:
Patel, N, Henry, A orcid.org/0000-0002-5379-6618 and Scarsbrook, A orcid.org/0000-0002-4243-032X (2019) The value of MR textural analysis in prostate cancer. Clinical Radiology, 74 (11). pp. 876-885. ISSN 0009-9260

https://doi.org/10.1016/j.crad.2018.11.007

Table 1: ISUP grade and Gleason Grade comparison.

ISUP Grade	Old Gleason Grade equivalent
1	GS ≤ 6
2	GS (3+4)
3	GS (4+3)
4	GS 8
5	GS ≥ 9

Table 2: Definitions and impacts of known textural features.

a) Histogram (first order) texture definitions and impacts.

Histogram features	Definition	Impact of feature
Mean	An average intensity value for all the pixels in a region of interest	Value will change depending on the intensity level of each pixel
Standard deviation (SD)	Measures the variation of pixel intensities about the mean within a region of interest	A low SD indicates that the pixel intensities in the region of interest are homogenous. A high SD indicates that the region of interest is heterogeneous
Skewness	Measures the asymmetry of the histogram of pixel intensities within a region of interest	Indicates the symmetry of the pixel intensities around the mean. Bright pixels will positively skew the histogram; darker pixels will negatively skew it
Kurtosis	Indicates how tall and sharp the central peak is relative to the normal distribution curve	If the difference in variation of pixel intensities is great, then the peak will be taller and sharper; if the variation is small then the peak will be flatter and shorter
Entropy$_{HIST}$	Refers to the number of different pixel intensities within a region of interest. Entropy is therefore a measure of disorder.	If there are a few pixel intensities present in an image then there is low entropy. It is at a maximum when all possible level of pixel intensities are present in a region.
Energy$_{HIST}$	Refers to the uniformity of an image.	The more homogenous/similar the pixel intensities are within a region of interest, the larger the value.
Mean of positive pixels (MPP)	Average of the pixels which have positive pixel intensities. Positive pixels are pixels that are brighter than the mean	Value changes depending on how the pixel intensities of the brightest pixels change

b) Matrix (second order) texture definitions.

Matrix Features	Definition
$Entropy_{GLCM}$	Measures disorder of pixel intensity relationships within a region of interest.
$Energy_{GLCM}$	Measures uniformity of pixel intensity relationships within a region of interest.
Contrast	Measures the quantity of local variations within pixel intensity relationships within an image
Correlation	Measures a potential connection between a pixel and its local neighbourhood of pixels

Table 3: A review table of prostate MRTA studies.

First author, year of publication (Ref number)	Final patient cohort size	Textural features studied	MR Equipment	Textural segmentation and software	MRI sequence	Significant textural feature results	Statistical test used	Limitations
1: Stember JN 2014 [44]	8	Average signal, SD, $Energy_{GLCM}$, Contrast, Correlation, Homogeneity and $Entropy_{GLCM}$	3T MRI Pelvic phased array coil	Single slice Matlab	T2w	Diagnosis: T2w energy, homogeneity	-	Retrospective Study Small sample size TZ cancer only TRUS biopsy
2: Wibmer A 2015 [36]	147	Haralick Features: $Energy_{GLCM}$, $Entropy_{GLCM}$, Correlation, Homogeneity, Inertia (contrast)	3T MRI Pelvic phased array and endorectal coil	Volume segmentation In house software Insight toolkit	T2w	Diagnosis PZ: Entropy, correlation, homogeneity and inertia ($p<0.0001$), energy ($p=0.008$) Diagnosis TZ: Correlation ($p=0.041$), Inertia ($p=0.001$) Characterisation: Inertia, Homogeneity	Wald test	Retrospective study Selection bias Pathology and MRI slices were not co-registered Freehand ROI

					DW	Diagnosis PZ: Energy, entropy, correlation, homogeneity, inertia ($p<0.0001$) Diagnosis TZ: Energy, entropy, correlation, homogeneity, inertia ($p<0.0001$) Characterisation: Energy, entropy		
3: **Vignati A** **2015** [46]	45	Contrast, Homogeneity	1.5T MRI Four channel phased array and endorectal coil	Single slice Octave	T2w	Characterisation: Contrast, homogeneity ($p<0.001$)	Spearman's Rank	Small sample size 2D texture analysis Selection bias Freehand ROI 1.5 Tesla magnet
					DW	Characterisation: Homogeneity (<0.001), contrast ($p=0.01$)		
4: **Fehr D 2015** [38]	147	First Order (Mean, SD, Skewness and Kurtosis) Haralick ($Energy_{GLCM}$, $Entropy_{GLCM}$, Homogeneity and Contrast)	3T MRI Pelvic phased array and endorectal coil	Volume segmentation Matlab Insight toolkit	T2w	Diagnosis: T2 kurtosis, skewness, mean ($p<0.001$), T2 correlation ($p=0.008$), T2 entropy ($p=0.018$), T2 contrast ($p=0.018$), Characterisation: T2 SD (TZ only)	t test	Retrospective study Selection bias Inconclusive as different classifiers show different results
					DW	Diagnosis: ADC mean, entropy, homogeneity, SD, energy, correlation, contrast, skewness, kurtosis (all $p<0.001$) Characterisation: ADC mean, skewness		

5: **Rozenberg R** **2016 [48]**	54	Skewness, Kurtosis, $Entropy_{HIST}$ RLNU	2 x 3T MRI Surface coil	Single slice MaZda	DW	Characterisation: Regression Model of kurtosis, entropy and skewness – AUC: 0.76 (P<0.001) and regression model of kurtosis, heterogeneity, entropy and skewness – AUC: 0.77 (p<0.001)	Spearman's Rank + Mann Whitney U	Retrospective study Small sample size Single tertiary-care centre study Selection bias Patients had TRUS biopsy before MRI Two scanners used
6: **Sidhu HS** **2016 [43]**	26	Kurtosis, $Entropy_{HIST}$, Skewness	1.5T MRI Pelvic phased array coil	Single slice TexRAD	T1w	Diagnosis: Entropy (p=0.004), result was independent of tumour inclusion in ROI	Mann Whitney U	TZ cancer only DCE MRI is done at a higher spatial resolution than most centres 1.5 Tesla magnet No standardised MRI protocol
					T2w	No significant findings		
		Kurtosis, $Entropy_{HIST}$, Skewness Mean			DW	Diagnosis: ADC kurtosis (p<0.001), became insignificant after exclusion of tumour from ROI, Median ADC entropy (p=0.005)		
7: **Nketiah G** **2016 [22]**	23	Matrix Features: ASM Contrast Correlation $Entropy_{GLCM}$	3T MRI Spine and body array receive coil	Single slice Matlab	T2w	Characterisation: ASM (p=0.033), entropy (p=0.033) Correlation with Median ADC: ASM (p<0.0001), contrast (p=0.049), entropy (<0.0001)	Point-biserial correlation + Spearman's Rank	Retrospective study Small sample size Selection bias 2D texture analysis

						No correlation between T2w textural features and median K^{trans}, median V_e		Pathology and MRI slices were not co-registered Freehand ROI GS 7 cancer only
8: **Gnep K 2017** [47]	74	Six histogram and 130 matrices features	2 x 3T MRI Six channel cardiac phased array	Volume segmentation Matlab	T2w	Characterisation: Difference $entropy_{GLCM}$ (p=0.04), difference variance (p=0.03)	Spearman's Rank + Cox Regression	Retrospective study Exclusion criteria used More features than participants PZ cancer only Selection bias Two scanners used
					DW	Characterisation: ADC contrast (p=0.04)		
9: **Bates A 2017** [45]	18	First Order (Mean, mean of positive pixels (MPP), SD, Skewness, Kurtosis and $Entropy_{HIST}$)	3T PET-MR N/A	Volume segmentation Texrad	T2w	PSMA positive expression: MPP, SD, Mean	Mann Whitney U	Retrospective study Small study sample size More features than participants TZ cancer only Conflict of interest
10: **Kuess P**	25		3T MRI	Volume segmentation	T2w	Diagnosis: Use for both first and second order	-	Retrospective study Small sample size
					DW			

2017 [49]		First and Second order features	Spine and body array receive coil	Matlab Insight toolkit	T1w	ADC and T2w most useful imaging sequences, DCE does not provide much more useful information		Selection bias 2D texture analysis Freehand ROI

Table 4: Potential features of interest warranting further study.

	Peripheral zone (PZ)	**Transition zone (TZ)**
Diagnosis	T2w: mean, $entropy_{GLCM}$, correlation, $energy_{GLCM}$	T2w: correlation, contrast
	ADC: mean, SD, skewness, kurtosis, $energy_{GLCM}$, $entropy_{GLCM}$, homogeneity, correlation, contrast	ADC: mean, SD, skewness, kurtosis, $entropy_{HIST}$, $energy_{GLCM}$, $entropy_{GLCM}$, homogeneity, correlation, contrast
		T1w: $entropy_{HIST}$
Characterisation	T2w: homogeneity, contrast, SD	
	ADC: mean, skewness, contrast, homogeneity, $energy_{GLCM}$, $entropy_{GLCM}$	