

Supplementary Table 1. the list of nuclear features in this study

Feature category	Nuclear feature name from Cellprofiler	
Nucleus shape related features	Area	
	Compactness	
	Eccentricity	
	Extent	
	FormFactor	
	MajorAxisLength	
	MaxFeretDiameter	
	MaximumRadius	
	MeanRadius	
	MedianRadius	
	MinFeretDiameter	
	MinorAxisLength	
	Orientation	
	Perimeter	
	Solidity	
	Nuclei_RadialDistribution_FracAtD_1of4	
	Nuclei_RadialDistribution_FracAtD_2of4	
	Nuclei_RadialDistribution_FracAtD_3of4	
	Nuclei_RadialDistribution_FracAtD_4of4	
	Nuclei_RadialDistribution_MeanFrac_1of4	
	Nuclei_RadialDistribution_MeanFrac_2of4	
	Nuclei_RadialDistribution_MeanFrac_3of4	
	Nuclei_RadialDistribution_MeanFrac_4of4	
	Nuclei_RadialDistribution_RadialCV_1of4	
	Nuclei_RadialDistribution_RadialCV_2of4	
	Nuclei_RadialDistribution_RadialCV_3of4	
	Nuclei_RadialDistribution_RadialCV_4of4	
	Intra nuclear texture related features	AngularSecondMoment_0
		AngularSecondMoment_135
		AngularSecondMoment_45
		AngularSecondMoment_90
		Contrast_0
Contrast_135		
Contrast_45		
Contrast_90		
Correlation_0		
Correlation_135		
Correlation_45		
Correlation_90		
DifferenceEntropy_0		
DifferenceEntropy_135		
DifferenceEntropy_45		
DifferenceEntropy_90		
DifferenceVariance_0		
DifferenceVariance_135		
DifferenceVariance_45		
DifferenceVariance_90		
Entropy_0		
Entropy_135		
Entropy_45		
Entropy_90		
InfoMeas_0		
InfoMeas_135		
InfoMeas_45		
InfoMeas_90		
InfoMeas2_0		
InfoMeas2_135		
InfoMeas2_45		
InfoMeas2_90		
InverseDifferenceMoment_0		
InverseDifferenceMoment_135		
InverseDifferenceMoment_45		
InverseDifferenceMoment_90		
SumAverage_0		
SumAverage_135		
SumAverage_45		
SumAverage_90		
SumEntropy_0		
SumEntropy_135		
SumEntropy_45		
SumEntropy_90		
SumVariance_0		
SumVariance_135		
SumVariance_45		
SumVariance_90		
Variance_Gray_0		
Variance_135		
Variance_45		
Variance_90		

Cellprofiler features

<http://cellprofiler-manual.s3.amazonaws.com/CellProfiler-3.0.0/modules/measurement.html>

Supplementary Table 2. The results of probability to each group calculated by SVM and RF models in the validation.

(a) SVM-based model

Case	Truth Group	Prediction Group	Rec(+) probability	Rec(-) probability
1	-	-	0.04	0.96
2	+	+	0.63	0.37
3	-	-	0.19	0.81
4	-	-	0.11	0.89
5	+	+	0.73	0.27
6	-	-	0.17	0.83
7	-	-	0.21	0.79
8	-	-	0.25	0.75
9	+	+	0.69	0.31
10	-	-	0.11	0.89
11	-	-	0.47	0.53
12	+	+	0.66	0.34
13	+	+	0.59	0.41
14	+	+	0.90	0.10
15	+	+	0.64	0.36
16	+	+	0.91	0.09
17	-	+	0.63	0.37
18	+	+	0.71	0.29
19	+	+	0.73	0.27
20	+	+	0.82	0.18
21	+	+	0.72	0.28
22	-	+ / -	0.50	0.50
23	-	+	0.55	0.45
24	-	-	0.37	0.63
25	-	-	0.37	0.63
26	-	-	0.28	0.72
27	-	-	0.19	0.81
28	-	-	0.31	0.69
29	-	-	0.23	0.77
30	-	-	0.28	0.72

(b) RF-based model

Case	Truth Group	Prediction Group	Rec(+) probability	Rec(-) probability
1	-	-	0.37	0.63
2	+	+	0.62	0.38
3	-	-	0.36	0.64
4	-	-	0.36	0.64
5	+	+	0.61	0.39
6	-	-	0.32	0.68
7	-	-	0.24	0.76
8	-	-	0.26	0.74
9	+	+	0.72	0.28
10	-	-	0.29	0.71
11	-	+	0.53	0.47
12	+	+	0.64	0.36
13	+	+	0.67	0.33
14	+	+	0.74	0.26
15	+	+	0.64	0.36
16	+	+	0.76	0.24
17	-	+	0.73	0.27
18	+	+	0.63	0.37
19	+	+	0.71	0.29
20	+	+	0.74	0.26
21	+	+	0.62	0.38
22	-	+	0.60	0.40
23	-	+	0.70	0.30
24	-	-	0.36	0.64
25	-	-	0.20	0.80
26	-	-	0.41	0.59
27	-	-	0.29	0.71
28	-	-	0.33	0.67
29	-	-	0.33	0.67
30	-	-	0.29	0.71

Abbreviations: Rec, recurrence within 2-years; SVM, support vector machine; RF, random forest
 The cases of misjudgment and undecidable are indicated in gray color.

Supplementary Table 3. The top 20 morphological features with highly contributions to recurrence and non-recurrence in the SVM model.

(A) Top 20 of highly contributed features to Recurrence

A	B	C	D	E	F	G
Feature No.	Feature Name	Feature group	Method	Neighborhood	Haralick Feature	Weight
F002	Area	1	Stdev	NI	NI	43.918
F001	Area	1	Average	NI	NI	33.486
F707	Entropy_max	3	ROI	Nearest	Contrast	8.628
F284	MeanRadius	2	Case	Circle	Contrast	8.265
F269	MeanRadius	2	Case	Nearest	Contrast	7.945
F119	Extent	2	Group	Circle	Contrast	6.235
F616	Correlation_max	3	Group	Nearest	Contrast	5.878
F717	Entropy_max	3	Case	Nearest	Contrast	5.69
F712	Entropy_max	3	Group	Nearest	Contrast	5.649
F631	Correlation_max	3	Group	Circle	Contrast	5.401
F867	SumEntropy_max	3	ROI	Circle	Contrast	5.084
F124	Extent	2	Case	Nearest	Contrast	4.942
F296	MedianRadius	2	Group	Nearest	Contrast	4.926
F520	MeanFrac_ratio	2	Group	Nearest	Contrast	4.78
F168	MajorAxisLength	2	Group	Nearest	Contrast	4.518
F264	MeanRadius	2	Group	Circle	Contrast	4.479
F338	MinFerretDiameter	2	ROI	Circle	Contrast	3.992
F732	Entropy_max	3	Case	Nearest	Contrast	3.737
F424	Perimeter	2	Group	Circle	Contrast	3.587
F311	MedianRadius	2	Group	Circle	Contrast	3.521

Abbreviation,

Feature group 1 is nuclei average of standard deviation of ROI

Feature group 2 is nucleus shape related CFLCM heterogeneity feature

Feature group 3 is intra nucleus texture related CFLCM heterogeneity feature

A: Feature's number in analysis, B: Features name from CellProfiler, C: Group of feature name on line B, D: CFLCM calculation base

E: CFLCM neighborhood selection method, F: Haralick function, G: Weight on SVM model

Cell Profiler features:

<http://cellprofiler-manual.s3.amazonaws.com/CellProfiler-3.0.0/modules/measurement.html>

CFLCM Method: Reference [14]

NI: no information

(B) Top 20 of highly contributed features to non-Recurrence

A	B	C	D	E	F	G
Feature No.	Feature Name	Feature group	Method	Neighborhood	Haralick Feature	Weight
F136	FormFactor	2	Group	Nearest	Contrast	-13.061
F141	FormFactor	2	Case	Nearest	Contrast	-10.837
F562	AngularSecondMoment_max	3	ROI	Circle	Contrast	-9.272
F456	Solidity	2	Group	Nearest	Contrast	-9.128
F151	FormFactor	2	Group	Circle	Contrast	-8.676
F904	SumVariance_max	3	Group	Nearest	Contrast	-6.845
F099	Extent	2	ROI	Nearest	Contrast	-6.104
F572	AngularSecondMoment_max	3	Case	Circle	Contrast	-5.907
F919	SumVariance_max	3	Group	Circle	Contrast	-5.67
F156	FormFactor	2	Case	Circle	Contrast	-5.291
F082	Eccentricity	2	ROI	Circle	Contrast	-5.275
F840	SumAverage_max	3	Group	Nearest	Contrast	-5.2
F200	MaxFeretDiameter	2	Group	Nearest	Contrast	-4.994
F557	AngularSecondMoment_max	3	Case	Nearest	Contrast	-4.713
F215	MaxFeretDiameter	2	Group	Circle	Contrast	-4.478
F584	Contrast_max	3	Group	Nearest	Contrast	-4.186
F508	FracAtD_ratio	2	Case	Circle	Contrast	-4.172
F195	MaxFeretDiameter	2	ROI	Nearest	Contrast	-4.142
F658	DifferenceEntropy_max	3	ROI	Circle	Contrast	-4.106
F471	Solidity	2	Group	Circle	Contrast	-4.075

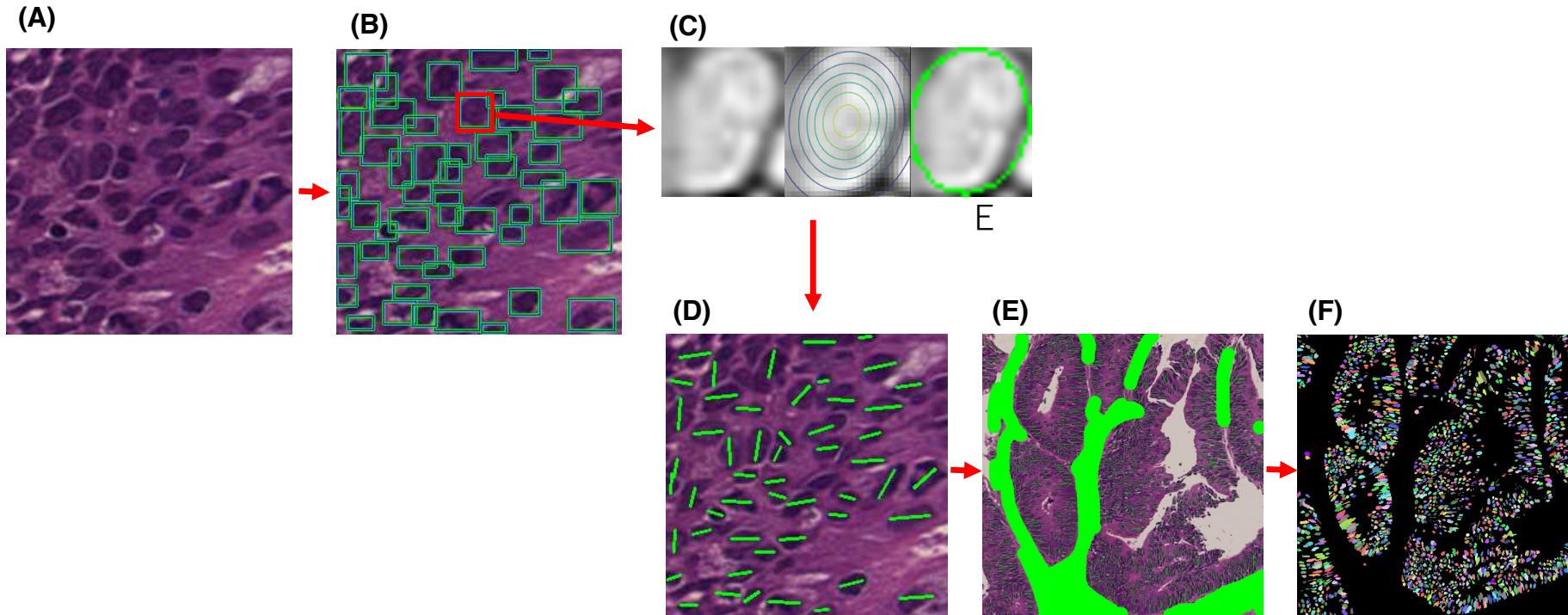
Supplementary Table 4. Results of out of bag (OOB) error in RF model

OOB estimate of error rate : 15.6%

Confusion matrix		Prediction		
		Rec (+)	Rec (-)	Total
Truth	Rec (+)	262	66	328
	Rec (-)	43	327	370
	Total	305	393	698

Abbreviations: Rec, recurrence within 2-years

Supplementary Figure 1. Segmentation mask creation of the touching nuclei



(A) original HE image (B) nucleus shape and area were detected using trained YOLO v3 model. (C) The nucleus image was changed to black-and-white, and the region was concentrically expanded from the center of the nucleus to extract the nucleus contour line. (D) and (E) the image showed nucleus maximum axis as process intermediate images, to check if individual nuclei were recognized, (F) a new additional segmentation mask. To construct segmentation process as a general-purpose process, we used colorectal cancer images for learning, because which is the highest cellularity tissue among cancer.

Supplementary Figure 2. An illustration of the machine learning application in the clinical management of non-muscle invasive bladder cancer

