

Radiomska analiza ^{18}F -FDG PET/CT odziva na radioterapijo in kemoterapijo pri pacientih s pljučnim rakom

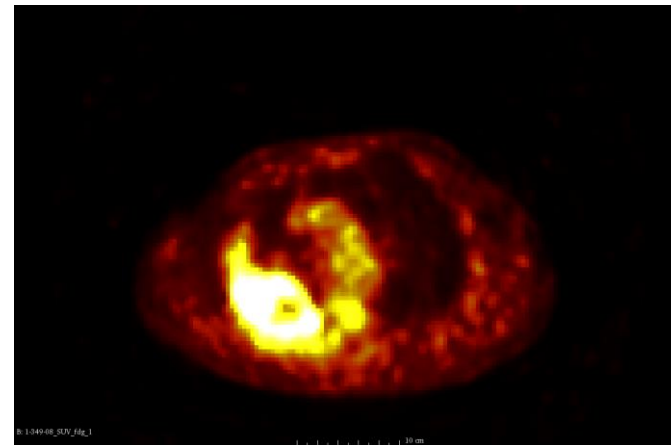
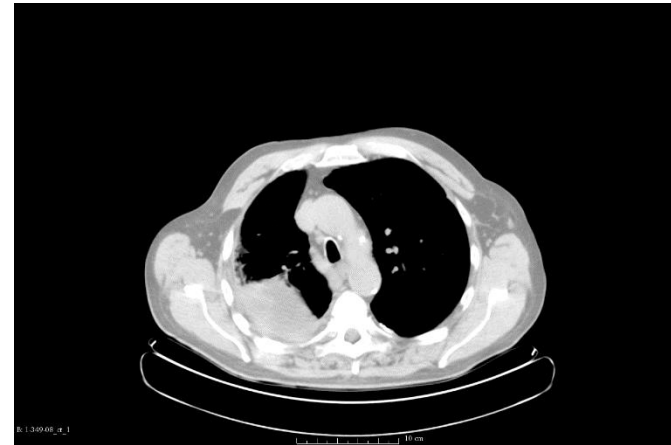
Damijan Valentinuzzi, Martina Vrankar, Urban Simončič, Robert Jeraj

3. konferenca ŠFOSM

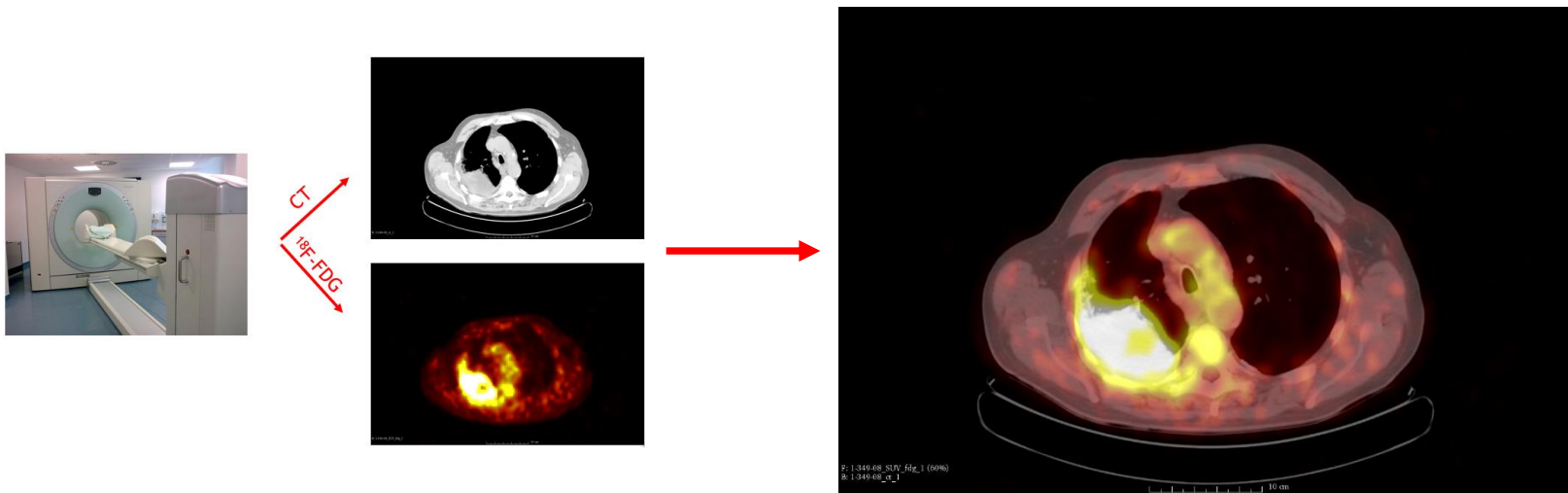
Reaktorski center Podgorica, 29. 2. 2016



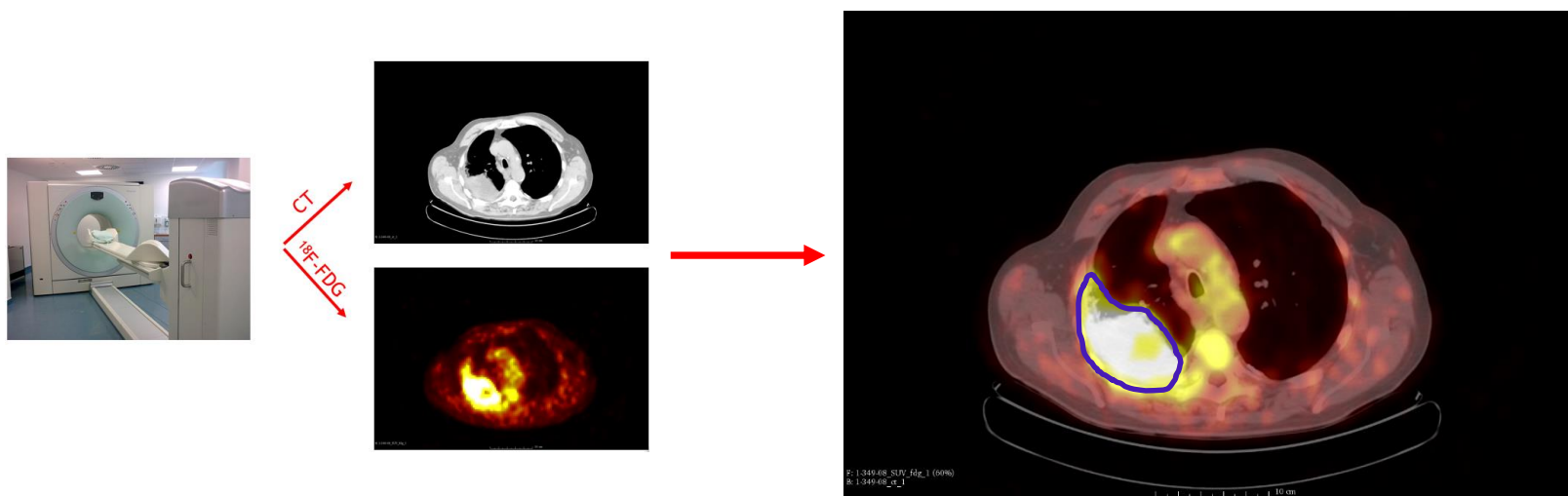
PET/CT - klinična uporaba



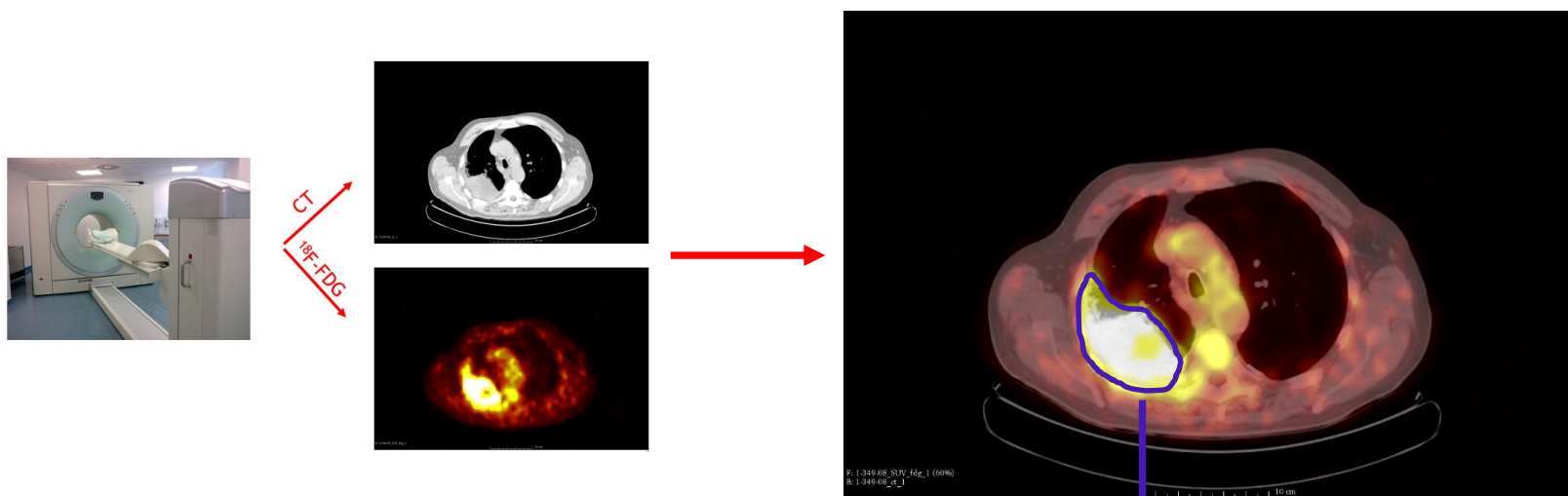
PET/CT - klinična uporaba



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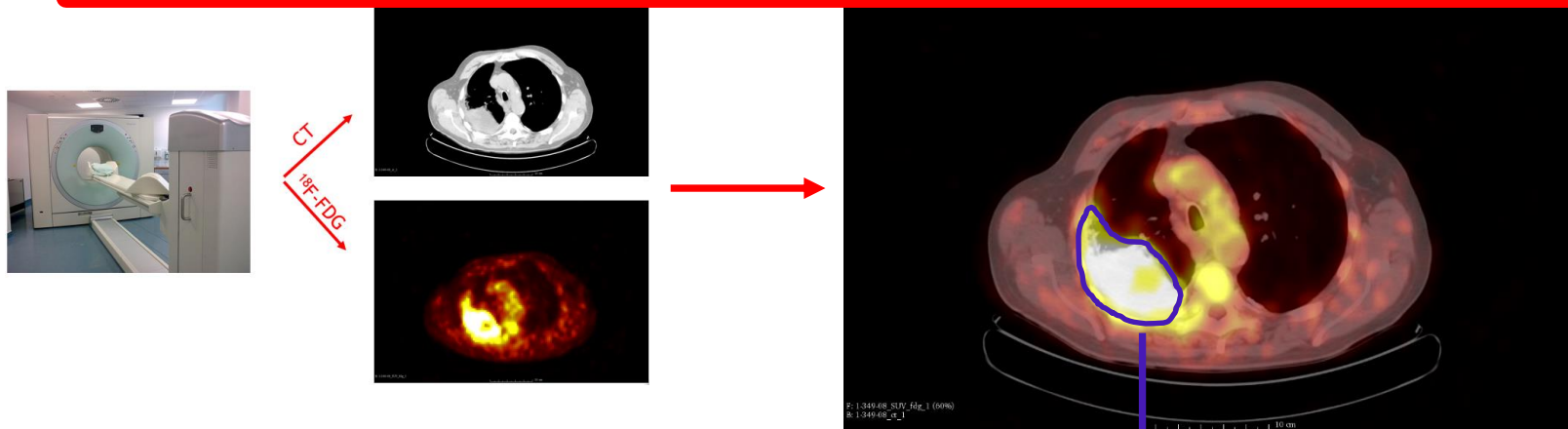
CT: $HU = 1000 \times \frac{\mu - \mu_{voda}}{\mu_{voda} - \mu_{zrak}}$ (Hounsfieldove enote)

PET: $SUV = \frac{c(t)}{ID/BW}$ (Standardized uptake value), SUV_{max} , SUV_{mean} , SUV_{peak} , ...



PET/CT - klinična uporaba

Ali lahko iz PET/CT slike
dobimo še več informacij?



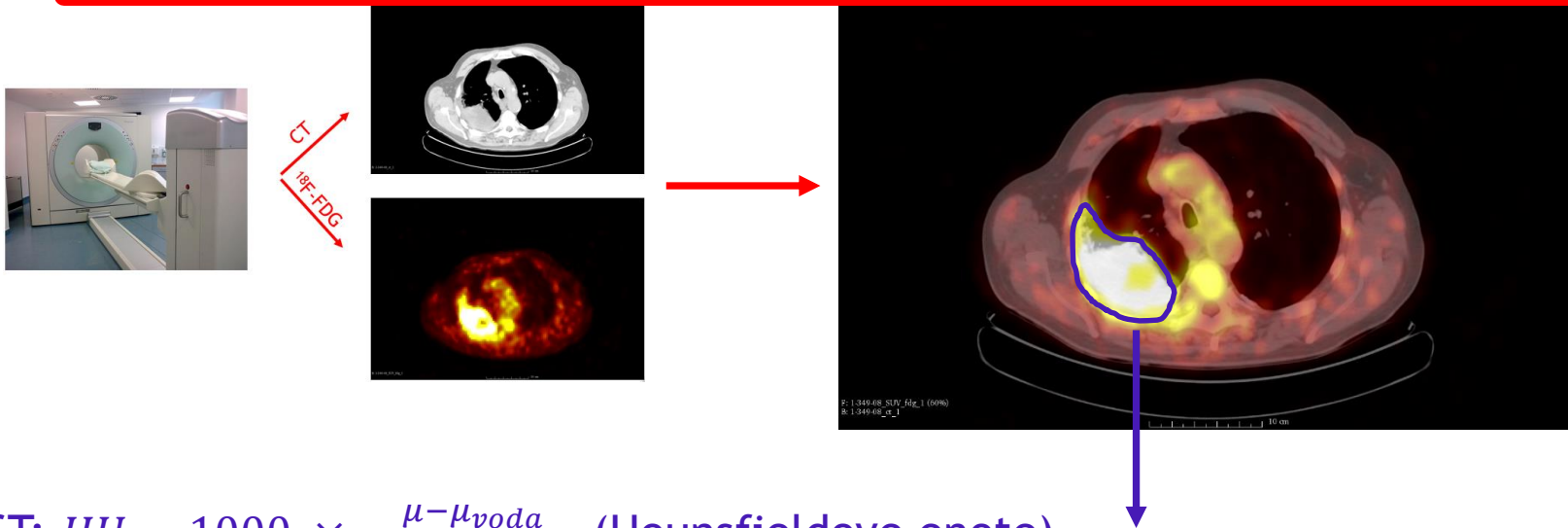
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PET/CT - klinična uporaba

Ali lahko iz PET/CT slike pred terapijo napovemo odziv?

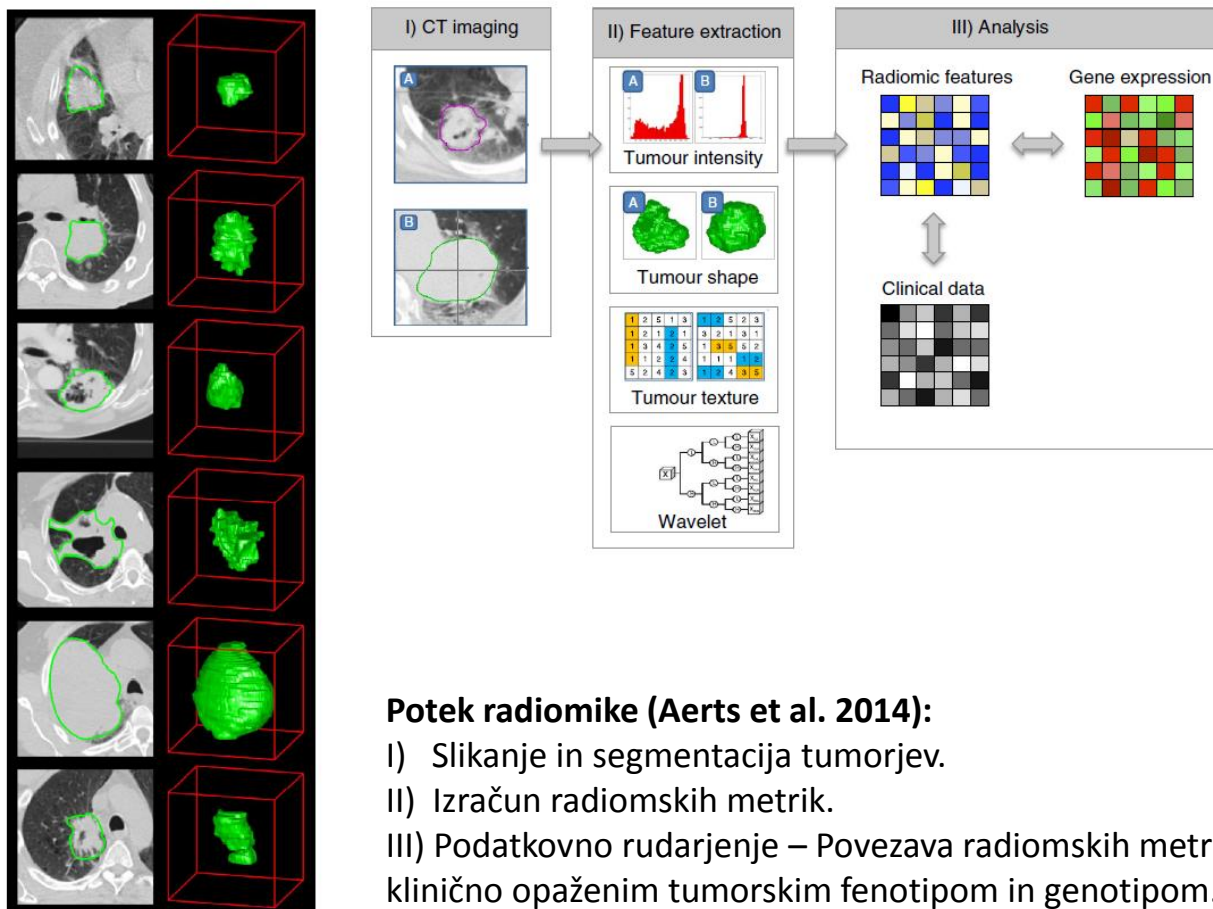


CT: $HU = 1000 \times \frac{\mu - \mu_{voda}}{\mu_{voda} - \mu_{zrak}}$ (Hounsfieldove enote)

PET: $SUV = \frac{c(t)}{ID/BW}$ (Standardized uptake value), SUV_{max} , SUV_{mean} , SUV_{peak} , ...



RADIOMIKA



TEKSTURNE METRIKE

- Primer: Coarseness, Contrast, Busyness, Complexity.
- Izračun temelji na NGTDM (Neighborhood grey-tone difference matrix) (Amadasum et. al (1989)).)

$$s(i) = \begin{cases} \sum |i - \bar{A}_i|, & i \in N_i, N_i \neq 0 \\ 0, & N_i = 0 \end{cases}$$

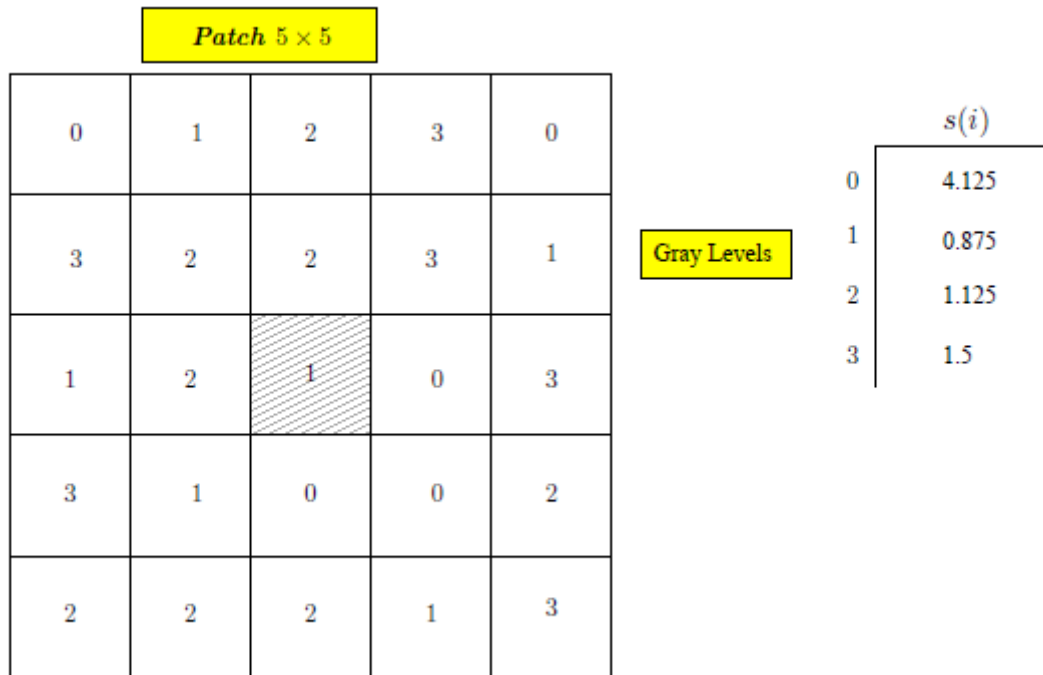
$$\bar{A}_i = \bar{A}(k,l) = \frac{1}{(2d+1)^2-1} \left[\sum_{m=-d}^d \sum_{n=-d}^d I(k+m, l+n) \right], (m,n) \neq 0$$

N_i ... Vsi piksli z vrednostjo i .



TEKSTURNE METRIKE

$$s(1) = \left|1 - \frac{10}{8}\right| + \left|1 - \frac{13}{8}\right| = 0.875$$



TEKSTURNE METRIKE

$$\text{Coarseness} = \frac{1}{\epsilon + \sum_{i=0}^{N_H} s(i)r(i)}$$

$$\text{Contrast} = \frac{1}{N_g(N_g-1)} \sum_{i=0}^{N_H} \sum_{j=0}^{N_H} r_i r_j (i-j)^2 \left[\frac{1}{n^2} \sum_{i=0}^{N_H} s(i) \right]$$

$$\text{Busyness} = \frac{\sum_{i=0}^{N_H} s(i)r(i)}{\sum_{i=0}^{N_H} \sum_{j=0}^{N_H} i r_i - j r_j}, \quad r_i \neq 0 \quad r_j \neq 0$$

$$\text{Complexity} = \sum_{i=0}^{N_H} \sum_{j=0}^{N_H} \frac{|i-j|}{n^2(r_i+r_j)} [r_i s(i) + r_j s(j)], \quad r_i \neq 0 \quad r_j \neq 0$$

$r_i = \frac{N_i}{n^2}$... Verjetnost za vrednost i v sliki.

$n = N - 2d, N = N_x = N_y$ (Dimenzija slike).

d ... Velikost patch-a (ponavadi 5 (5 x 5)).

N_g ... Število različnih vrednosti i v sliki.

N_H ... Najvišja vrednost i v sliki.



ŠTUDIJA

- Retrospektivna študija (2007-2015).
- Onkološki inštitut Ljubljana.
- 51 pacientov (30 moških, 21 žensk, 30-82 let, povprečna starost 62,4 leta).
- Lokalno napredovani (47) in metastatski (4) pljučni rak.
- Kemoterapija in/ali radioterapija.
- Vsak pacient slikan 2 - 6 krat.



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METODE

- Segmentacija tumorjev s pomočjo izkušenega onkologa.
- Radiomika na ^{18}F -FDG PET in CT.
- Izračun **13** (PET) oz. **12** (CT) **1-D teksturnih metrik** in **41 3-D teksturnih metrik** s pomočjo “in house” skript (UW-Madison, WI).
- Razdelitev pacientov glede na odziv po RECIST. *
 - **CR (Complete response)** vs. **Others**.
- *RECIST (response evaluation criteria in solid tumours).
- Mann-Whitney U-test za iskanje statistično značilnih razlik v vrednosti radiomskih metrik med obema skupinama.



PRELIMINARNI REZULTATI

FDG & CT 1-D teksturne metrike

1D Texture Features	Mean (CR)	SD (CR)	Mean (Others)	SD (Others)	p (Mann-Whitney)	h (Mann-Whitney)
SUVmax	10,5	5,93	18,2	6,15	0,000361	1
SUVmean	5,23	2,02	7,35	2,12	0,00207	1
SUVmedian	4,93	1,78	6,8	2,09	0,00767	1
SUVpeak	8,67	4,98	14,6	5,18	0,000814	1
SUVtotal	8880	13600	12400	11000	0,0446	1
SUVstd	1,9	1,44	3,36	1,45	0,00243	1
SUVcov	0,32	0,159	0,441	0,0962	0,0126	1
FDG Volume	95,4	153	97,9	76,7	0,144	0
TLG	565	874	731	626	0,05	1
FDG Skewness	0,428	0,332	0,782	0,75	0,0817	0
FDG Kurtosis	-0,535	0,548	0,674	3,57	0,086	0
FDG Energy	0,0181	0,0458	0,00322	0,0093	0,105	0
FDG Entropy	5,9	1,99	6,9	1,21	0,122	0

1D Texture Features	Mean (CR)	SD (CR)	Mean (Others)	SD (Others)	p (Mann-Whitney)	h (Mann-Whitney)
HUmax	571	414	483	220	0,865	0
HUmean	2,86	58,6	-1,64	55	0,184	0
HUmedian	13	50,9	22	17,9	0,348	0
HUpeak	156	154	177	97	0,635	0
HUtotal	808000	1320000	378000	1030000	0,567	0
HUstd	85,7	37,4	96,5	71,3	0,855	0
HUcov	6,83	44,6	1,87	32,3	0,312	0
CT Volume	95,6	153	98,3	76,7	0,147	0
CT Skewness	-0,15	2,25	-1,5	1,3	0,0243	1
CT Kurtosis	11,4	15	7,36	7,05	0,67	0
CT Energy	0,00725	0,00283	0,00646	0,00226	0,429	0
CT Entropy	5,27	0,381	5,46	0,38	0,193	0

PRELIMINARNI REZULTATI FDG 3-D teksturne metrike

3D Texture Features	Mean (CR)	SD (CR)	Mean (Others)	SD (Others)	p (Mann-Whitney)	h (Mann-Whitney)
FDG Angular Moment	0,0145	0,000213	0,0147	0,000159	0,0312	1
FDG Contrast-GLCM	2280	672	1970	557	0,0529	0
FDG Correlation	0,675	0,0858	0,709	0,0556	0,134	0
FDG Sum of Squares Variance	18600	3700	15900	2410	0,0102	1
FDG Inverse Difference Moment	0,029	0,00649	0,0332	0,00442	0,0154	1
FDG Sum Average	239	31,4	215	20,6	0,00824	1
FDG Sum Variance	10700	1540	10200	1380	0,336	0
FDG Sum Entropy	4,12	0,0245	4,1	0,0195	0,0312	1
FDG Entropy-GLCM	4,25	0,0098	4,24	0,00704	0,0396	1
FDG Difference Variance	762	214	689	193	0,238	0
FDG Difference Entropy	3,75	0,0707	3,71	0,0605	0,0188	1
FDG Information Measure of Correlation 1	-0,587	0,00545	-0,584	0,00348	0,128	0
FDG Information Measure of Correlation 2	0,985	0,000878	0,985	0,000602	0,111	0
FDG Maximal Correlation Coefficient	-32,5	0,251	-32,5	0,179	0,18	0
FDG Maximum Probability	0,0218	0,00169	0,0228	0,00125	0,0396	1
FDG Diagonal Moment	246	317	402	237	0,116	0
FDG Dissimilarity	37,6	5,84	34,3	4,6	0,0293	1
FDG Difference Energy	0,0269	0,00223	0,0285	0,00194	0,0165	1
FDG Inertia	2280	672	1970	557	0,0529	0
FDG Sum Energy	0,0173	0,000587	0,0177	0,000479	0,0293	1
FDG Cluster Shade	129000	197000	225000	123000	0,0953	0
FDG Cluster Prominance	291000000	68300000	282000000	57300000	0,932	0
FDG Small Run Emphasis	0,00358	0,00187	0,00463	0,00177	0,0472	1
FDG Long Run Emphasis	17900	3240	15800	2340	0,0144	1
FDG Gray-Level Nonuniformity	294	1,55	293	1,09	0,0331	1
FDG Run Length Nonuniformity	7,02	0,232	7,17	0,16	0,0201	1
FDG Run Percentage	0,233	0,000424	0,233	0,000306	0,0259	1
FDG Low Gray-Level Emphasis	0,995	0,00132	0,994	0,000928	0,0374	1
FDG High Gray-Level Emphasis	1,02	0,00577	1,02	0,00433	0,0188	1
FDG Short Run Low Gray-Level Emphasis	0,00355	0,00183	0,00457	0,00172	0,05	1
FDG Short Run High Gray-Level Emphasis	0,00374	0,00205	0,00494	0,00207	0,05	1
FDG Long Run Low Gray-Level Emphasis	17900	3210	15700	2320	0,0135	1
FDG Long Run High Gray-Level Emphasis	18300	3360	16100	2430	0,0188	1
FDG Small Number Emphasis	0,974	0,00702	0,969	0,00501	0,0259	1
FDG Large Number Emphasis	0,0569	0,0167	0,0673	0,0126	0,0374	1
FDG Number Nonuniformity	0,91	0,0218	0,897	0,0151	0,0259	1
FDG Second Moment	0,0448	0,000889	0,0453	0,000512	0,0735	0
FDG Entropy-NGL	3,14	0,015	3,13	0,00861	0,056	0
FDG Coarseness	0,0801	0,0263	0,102	0,0269	0,0176	1
FDG Contrast-NGL	937	396	783	476	0,0697	0
FDG Busyness	0,0443	0,0117	0,0385	0,00671	0,0735	0



PRELIMINARNI REZULTATI CT 3-D teksturne metrike

3D Texture Features	Mean (CR)	SD (CR)	Mean (Others)	SD (Others)	p (Mann-Whitney)	h (Mann-Whitney)
CT Angular Moment	0,0151	0,000393	0,0153	0,000771	0,519	0
CT Contrast-GLCM	2750	611	2750	488	0,971	0
CT Correlation	0,293	0,136	0,293	0,111	0,635	0
CT Sum of Squares Variance	26300	5470	27800	5060	0,349	0
CT Inverse Difference Moment	0,0403	0,0116	0,0418	0,0121	0,519	0
CT Sum Average	300	34,9	309	31,9	0,443	0
CT Sum Variance	5680	1650	5730	1200	0,361	0
CT Sum Entropy	3,97	0,0617	3,96	0,0527	0,618	0
CT Entropy-GLCM	4,22	0,017	4,21	0,0219	0,551	0
CT Difference Variance	1080	169	1100	137	0,551	0
CT Difference Entropy	3,66	0,0891	3,65	0,0908	0,415	0
CT Information Measure of Correlation 1	-0,553	0,014	-0,551	0,0129	0,779	0
CT Information Measure of Correlation 2	0,979	0,00314	0,979	0,00311	0,742	0
CT Maximal Correlation Coefficient	-31,3	0,813	-31,1	0,583	0,779	0
CT Maximum Probability	0,0257	0,00211	0,0267	0,00356	0,635	0
CT Diagonal Moment	-379	322	-441	310	0,415	0
CT Dissimilarity	37,9	5,7	37,7	4,66	0,874	0
CT Difference Energy	0,0308	0,00378	0,0313	0,00406	0,401	0
CT Inertia	2750	611	2750	488	0,971	0
CT Sum Energy	0,0212	0,00184	0,0215	0,00172	0,635	0
CT Cluster Shade	-215000	173000	-244000	165000	0,415	0
CT Cluster Prominance	140000000	62900000	149000000	58900000	0,247	0
CT Small Run Emphasis	0,00675	0,00186	0,00835	0,00843	0,913	0
CT Long Run Emphasis	26200	5040	27700	4810	0,349	0
CT Gray-Level Nonuniformity	290	2,53	290	3,16	0,473	0
CT Run Length Nonuniformity	8,66	0,79	8,8	0,73	0,742	0
CT Run Percentage	0,232	0,000701	0,232	0,000931	0,458	0
CT Low Gray-Level Emphasis	0,992	0,00223	0,991	0,00282	0,473	0
CT High Gray-Level Emphasis	1,03	0,00976	1,04	0,0144	0,519	0
CT Short Run Low Gray-Level Emphasis	0,00662	0,00174	0,00782	0,00664	0,798	0
CT Short Run High Gray-Level Emphasis	0,00752	0,0028	0,0115	0,0195	0,893	0
CT Long Run Low Gray-Level Emphasis	25900	4960	27400	4690	0,349	0
CT Long Run High Gray-Level Emphasis	27200	5400	28900	5350	0,401	0
CT Small Number Emphasis	0,957	0,011	0,954	0,0128	0,458	0
CT Large Number Emphasis	0,103	0,0336	0,121	0,0755	0,503	0
CT Number Nonuniformity	0,86	0,0294	0,855	0,032	0,488	0
CT Second Moment	0,0495	0,00194	0,0498	0,0018	0,706	0
CT Entropy-NGL	3,06	0,0311	3,05	0,0287	0,724	0
CT Coarseness	0,0526	0,0121	0,0529	0,0126	0,893	0
CT Contrast-NGL	1440	528	1460	442	0,874	0
CT Busyness	0,0715	0,0114	0,0777	0,0256	0,601	0



NADALJNJE DELO

- Razdelitev pacientov v bolj homogene skupine glede na diagnozo in način zdravljenja (stadij bolezni, kemoterapija, radioterapija, doza...).
- Razdelitev pacientov več 4 skupine glede na RECIST (CR-complete response, PR-partial response, SD-stable disease, PD-progressive disease).
- Analiza preživetja (Kaplan-Meier curves).
- Log-rank test.
- Cox regression.



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