Chart, line chart

Description automatically generated

Supplementary Figure 1. CIs of external validation. (a)CIs of external validation in LUNG 1 dataset; (b)CIs of external validation in LUNG 4 dataset; (c)CIs of external validation in H&N1 dataset; (d)CIs of external validation in OPC dataset.

Chart

Description automatically generated

Supplementary Figure 2. Marginal effect of combining volume and TNM staging to deep features and radiomics in head-and-neck cancer prognostic predication. (a) Marginal effect of TNM staging in H&N 1 datasets; (b) Marginal effect of volume in H&N 1 datasets; (c) Marginal effect of TNM staging in LUNG 1 datasets; (d) Marginal effect of volume in LUNG 1 datasets; (e) Marginal effect of (c) Marginal effect of volume in LUNG 1 datasets; (d) Marginal effect of TNM staging in LUNG 1 datasets in LUNG 4 datasets; (f) Marginal effect of volume in LUNG 4 datasets

Chart

Description automatically generated

Supplementary Figure 3. Violin plot of reproducibility result in test/retest setting. (a) CCC distribution of radiomics features in RIDER dataset; (b) CCC distribution of deep features in RIDER dataset.

Diagram

Description automatically generated

Supplementary Figure 4. Violin plot of reproducibility result in across modality setting. (a) CCC distribution of radiomics features in ABCs dataset; (b) CCC distribution of radiomics features (except shape related features) in ABCs dataset; (c) CCC distribution of deep features in ABCs dataset.

Supplementary Table 1. Index of available patients for pre-treatment survival predication in LUNG 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| LUNG4-003 | LUNG4-084 | LUNG4-180 | LUNG4-240 | LUNG4-307 | LUNG4-347 |
| LUNG4-016 | LUNG4-089 | LUNG4-182 | LUNG4-245 | LUNG4-312 | LUNG4-349 |
| LUNG4-024 | LUNG4-096 | LUNG4-185 | LUNG4-255 | LUNG4-314 | LUNG4-352 |
| LUNG4-026 | LUNG4-113 | LUNG4-187 | LUNG4-259 | LUNG4-316 | LUNG4-354 |
| LUNG4-037 | LUNG4-114 | LUNG4-189 | LUNG4-270 | LUNG4-319 | LUNG4-355 |
| LUNG4-042 | LUNG4-115 | LUNG4-191 | LUNG4-271 | LUNG4-320 | LUNG4-360 |
| LUNG4-046 | LUNG4-118 | LUNG4-196 | LUNG4-272 | LUNG4-321 | LUNG4-362 |
| LUNG4-047 | LUNG4-125 | LUNG4-197 | LUNG4-276 | LUNG4-325 | LUNG4-376 |
| LUNG4-049 | LUNG4-129 | LUNG4-200 | LUNG4-277 | LUNG4-326 | LUNG4-380 |
| LUNG4-052 | LUNG4-135 | LUNG4-201 | LUNG4-278 | LUNG4-328 | LUNG4-381 |
| LUNG4-055 | LUNG4-136 | LUNG4-211 | LUNG4-279 | LUNG4-330 | LUNG4-383 |
| LUNG4-056 | LUNG4-139 | LUNG4-213 | LUNG4-280 | LUNG4-331 | LUNG4-384 |
| LUNG4-059 | LUNG4-141 | LUNG4-219 | LUNG4-282 | LUNG4-332 | LUNG4-391 |
| LUNG4-062 | LUNG4-143 | LUNG4-225 | LUNG4-285 | LUNG4-334 | LUNG4-393 |
| LUNG4-069 | LUNG4-158 | LUNG4-226 | LUNG4-286 | LUNG4-338 | LUNG4-396 |
| LUNG4-071 | LUNG4-169 | LUNG4-231 | LUNG4-298 | LUNG4-341 | LUNG4-397 |
| LUNG4-077 | LUNG4-171 | LUNG4-232 | LUNG4-299 | LUNG4-342 |  |
| LUNG4-078 | LUNG4-178 | LUNG4-239 | LUNG4-301 | LUNG4-345 |  |

Supplementary Table 2. Patient, tumour and patient characteristics dataset: Lung 1. MAASTRO NSCLC (n =422)

|  |  |
| --- | --- |
| Variable | Frequency (%) |
| Gender |  |
| male | 68.7 |
| female | 32.3 |
| T-stage |  |
| T1 | 22.0 |
| T2 | 37.0 |
| T3 | 12.6 |
| T4 | 27.7 |
| Tx | 0.7 |
| N-stage |  |
| N0 | 40.3 |
| N1 | 5.5 |
| N2 | 33.4 |
| N3 | 20.1 |
| Nx | 0.7 |
| TNM stage grouping |  |
| Stage I | 22.0 |
| Stage II | 9.5 |
| Stage IIIa | 26.5 |
| Stage IIIb | 41.9 |
| Treatment |  |
| Radiation only | 46.5 |
| Chemo-radiation | 53.5 |

Supplementary Table 3. Patient, tumour and patient characteristics dataset: Lung 4. MAASTRO NSCLC& SCLC (n =106)

|  |  |
| --- | --- |
| Variable | Frequency (%) |
| Gender |  |
| male | 64.1 |
| Female | 35.9 |
| T-stage |  |
| T1 | 12.3 |
| T2 | 31.1 |
| T3 | 17.9 |
| T4 | 38.7 |
| Tx | 0 |
| N-stage |  |
| N0 | 7.5 |
| N1 | 2.8 |
| N2 | 51.9 |
| N3 | 37.8 |
| Nx | 0 |
| TNM stage grouping |  |
| Stage I | 0 |
| Stage II | 0 |
| Stage III | 7.5 |
| Stage IIIa | 41.5 |
| Stage IIIb | 51.0 |
| Treatment |  |
| Radiation only | 12.3 |
| Chemo-radiation | 87.7 |

Supplementary Table 4. Patient, tumour and patient characteristics dataset: OPC. University of Toronto, HNSCC (n =605)

|  |  |
| --- | --- |
| Variable | Frequency (%) |
| Gender |  |
| male | 20.7 |
| Female | 70.3 |
| T-stage |  |
| T1 | 17.0 |
| T2 | 32.7 |
| T3 | 30.2 |
| T4 | 14.4 |
| Tx | 5.7 |
| N-stage |  |
| N0 | 16.7 |
| N1 | 10.1 |
| N2 | 65.6 |
| N3 | 7.6 |
| Nx | 0 |
| TNM stage grouping |  |
| Stage I | 1.8 |
| Stage II | 6.1 |
| Stage III | 14.0 |
| Stage IIIa | 65.0 |
| Stage IIIb | 13.1 |
| HPV status |  |
| Negative | 28.7(143/499) |
| Positive | 71.3(356/499) |

Supplementary Table 5. Patient, tumour and patient characteristics dataset: H&N 1 Maastro, HNSCC (n =137)

|  |  |
| --- | --- |
| Variable | Frequency (%) |
| Gender |  |
| male | 81.5 |
| Female | 18.5 |
| T-stage |  |
| T1 | 25.9 |
| T2 | 23.0 |
| T3 | 17.8 |
| T4 | 33.3 |
| Tx | 0 |
| N-stage |  |
| N0 | 45.2 |
| N1 | 11.9 |
| N2 | 40.7 |
| N3 | 2.2 |
| Nx | 0 |
| TNM stage grouping |  |
| Stage I | 18.5 |
| Stage II | 8.1 |
| Stage III | 17.0 |
| Stage IIIa | 54.3 |
| Stage IIIb | 2.2 |
| HPV status |  |
| Negative | 28.4 |
| Positive | 71.6 |
| Treatment |  |
| Radiation only | 74.1 |
| Chemo-radiation | 25.9 |

Supplementary Table 6. Parameters of params.yaml for radiomics extraction

|  |  |
| --- | --- |
| Parameters | Value |
| binWidth | 25 |
| interpolator | 'sitkBSpline' |
| resampledPixelSpacing | [2, 2, 2] |
| padDistance | 10 |
| resegmentRange | [-3, 3] |
| resegmentMode | sigma |
| voxelArrayShift | 1000 |
| label | 1 |

Supplementary Table 7. Radiomics features calculated by using Pyradiomics

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Features | Index | Features |
| 1 | original\_shape\_Elongation | 53 | original\_shape\_Flatness |
| 2 | original\_shape\_LeastAxisLength | 54 | original\_shape\_MajorAxisLength |
| 3 | original\_shape\_Maximum2DDiameterColumn | 55 | original\_shape\_Maximum2DDiameterRow |
| 4 | original\_shape\_Maximum2DDiameterSlice | 56 | original\_shape\_MeshVolume |
| 5 | original\_shape\_Maximum3DDiameter | 57 | original\_shape\_MinorAxisLength |
| 6 | original\_shape\_Sphericity | 58 | original\_shape\_SurfaceArea |
| 7 | original\_firstorder\_10Percentile | 59 | original\_glrlm\_LongRunLowGrayLevelEmphasis |
| 8 | original\_firstorder\_90Percentile | 60 | original\_glrlm\_LowGrayLevelRunEmphasis |
| 9 | original\_firstorder\_Energy | 61 | original\_glrlm\_RunEntropy |
| 10 | original\_firstorder\_Entropy | 62 | original\_glrlm\_RunLengthNonUniformity |
| 11 | original\_firstorder\_InterquartileRange | 63 | original\_glrlm\_RunLengthNonUniformityNormalized |
| 12 | original\_firstorder\_Kurtosis | 64 | original\_glrlm\_RunPercentage |
| 13 | original\_firstorder\_Maximum | 65 | original\_glrlm\_RunVariance |
| 14 | original\_firstorder\_Mean | 66 | original\_glrlm\_ShortRunEmphasis |
| 15 | original\_firstorder\_MeanAbsoluteDeviation | 67 | original\_glrlm\_ShortRunHighGrayLevelEmphasis |
| 16 | original\_firstorder\_Median | 68 | original\_glrlm\_ShortRunLowGrayLevelEmphasis |
| 17 | original\_firstorder\_Minimum | 69 | original\_glszm\_GrayLevelNonUniformity |
| 18 | original\_firstorder\_Range | 70 | original\_glszm\_GrayLevelNonUniformityNormalized |
| 19 | original\_firstorder\_RobustMeanAbsoluteDeviation | 71 | original\_glszm\_GrayLevelVariance |
| 20 | original\_firstorder\_RootMeanSquared | 72 | original\_glszm\_HighGrayLevelZoneEmphasis |
| 21 | original\_firstorder\_Skewness | 73 | original\_glszm\_LargeAreaEmphasis |
| 22 | original\_firstorder\_Uniformity | 74 | original\_glszm\_LargeAreaHighGrayLevelEmphasis |
| 23 | original\_firstorder\_Variance | 75 | original\_glszm\_LargeAreaLowGrayLevelEmphasis |
| 24 | original\_glcm\_Autocorrelation | 76 | original\_glszm\_LowGrayLevelZoneEmphasis |
| 25 | original\_glcm\_JointAverage | 77 | original\_glszm\_SizeZoneNonUniformity |
| 26 | original\_glcm\_ClusterProminence | 78 | original\_glszm\_SizeZoneNonUniformityNormalized |
| 27 | original\_glcm\_ClusterShade | 79 | original\_glszm\_SmallAreaEmphasis |
| 28 | original\_glcm\_ClusterTendency | 80 | original\_glszm\_SmallAreaHighGrayLevelEmphasis |
| 29 | original\_glcm\_Contrast | 81 | original\_glszm\_SmallAreaLowGrayLevelEmphasis |
| 30 | original\_glcm\_Correlation | 82 | original\_glszm\_ZoneEntropy |
| 31 | original\_glcm\_DifferenceAverage | 83 | original\_glszm\_ZonePercentage |
| 32 | original\_glcm\_DifferenceEntropy | 84 | original\_glszm\_ZoneVariance |
| 33 | original\_glcm\_DifferenceVariance | 85 | original\_gldm\_DependenceEntropy |
| 34 | original\_glcm\_JointEnergy | 86 | original\_gldm\_DependenceNonUniformity |
| 35 | original\_glcm\_JointEntropy | 87 | original\_gldm\_DependenceNonUniformityNormalized |
| 36 | original\_glcm\_Imc1 | 88 | original\_gldm\_DependenceVariance |
| 37 | original\_glcm\_Imc2 | 89 | original\_gldm\_GrayLevelNonUniformity |
| 38 | original\_glcm\_Idm | 90 | original\_gldm\_GrayLevelVariance |
| 39 | original\_glcm\_Idmn | 91 | original\_gldm\_HighGrayLevelEmphasis |
| 40 | original\_glcm\_Id | 92 | original\_gldm\_LargeDependenceEmphasis |
| 41 | original\_glcm\_Idn | 93 | original\_gldm\_LargeDependenceHighGrayLevelEmphasis |
| 42 | original\_glcm\_InverseVariance | 94 | original\_gldm\_LargeDependenceLowGrayLevelEmphasis |
| 43 | original\_glcm\_MaximumProbability | 95 | original\_gldm\_LowGrayLevelEmphasis |
| 44 | original\_glcm\_SumEntropy | 96 | original\_gldm\_SmallDependenceEmphasis |
| 45 | original\_glcm\_SumSquares | 97 | original\_gldm\_SmallDependenceHighGrayLevelEmphasis |
| 46 | original\_glrlm\_GrayLevelNonUniformity | 98 | original\_gldm\_SmallDependenceLowGrayLevelEmphasis |
| 47 | original\_glrlm\_GrayLevelNonUniformityNormalized | 99 | original\_ngtdm\_Busyness |
| 48 | original\_glrlm\_GrayLevelVariance | 100 | original\_ngtdm\_Coarseness |
| 49 | original\_glrlm\_HighGrayLevelRunEmphasis | 101 | original\_ngtdm\_Complexity |
| 50 | original\_glrlm\_LongRunEmphasis | 102 | original\_ngtdm\_Contrast |
| 51 | original\_glrlm\_LongRunHighGrayLevelEmphasis | 103 | original\_ngtdm\_Strength |
| 52 | original\_shape\_SurfaceVolumeRatio |  |  |

Supplementary Table 8. Label for Kinetics-400 Dataset

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Index | Label | Index | Label | Index | Label | Index |  |
| 0 | abseiling | 100 | drinking | 200 | moving furniture | 300 | shredding paper |
| 1 | air drumming | 101 | drinking beer | 201 | mowing lawn | 301 | shuffling cards |
| 2 | answering questions | 102 | drinking shots | 202 | news anchoring | 302 | side kick |
| 3 | applauding | 103 | driving car | 203 | opening bottle | 303 | sign language interpreting |
| 4 | applying cream | 104 | driving tractor | 204 | opening present | 304 | singing |
| 5 | archery | 105 | drop kicking | 205 | paragliding | 305 | situp |
| 6 | arm wrestling | 106 | drumming fingers | 206 | parasailing | 306 | skateboarding |
| 7 | arranging flowers | 107 | dunking basketball | 207 | parkour | 307 | ski jumping |
| 8 | assembling computer | 108 | dying hair | 208 | passing American football (in game) | 308 | skiing (not slalom or crosscountry) |
| 9 | auctioning | 109 | eating burger | 209 | passing American football (not in game) | 309 | skiing crosscountry |
| 10 | baby waking up | 110 | eating cake | 210 | peeling apples | 310 | skiing slalom |
| 11 | baking cookies | 111 | eating carrots | 211 | peeling potatoes | 311 | skipping rope |
| 12 | balloon blowing | 112 | eating chips | 212 | petting animal (not cat) | 312 | skydiving |
| 13 | bandaging | 113 | eating doughnuts | 213 | petting cat | 313 | slacklining |
| 14 | barbequing | 114 | eating hotdog | 214 | picking fruit | 314 | slapping |
| 15 | bartending | 115 | eating ice cream | 215 | planting trees | 315 | sled dog racing |
| 16 | beatboxing | 116 | eating spaghetti | 216 | plastering | 316 | smoking |
| 17 | bee keeping | 117 | eating watermelon | 217 | playing accordion | 317 | smoking hookah |
| 18 | belly dancing | 118 | egg hunting | 218 | playing badminton | 318 | snatch weight lifting |
| 19 | bench pressing | 119 | exercising arm | 219 | playing bagpipes | 319 | sneezing |
| 20 | bending back | 120 | exercising with an exercise ball | 220 | playing basketball | 320 | sniffing |
| 21 | bending metal | 121 | extinguishing fire | 221 | playing bass guitar | 321 | snorkeling |
| 22 | biking through snow | 122 | faceplanting | 222 | playing cards | 322 | snowboarding |
| 23 | blasting sand | 123 | feeding birds | 223 | playing cello | 323 | snowkiting |
| 24 | blowing glass | 124 | feeding fish | 224 | playing chess | 324 | snowmobiling |
| 25 | blowing leaves | 125 | feeding goats | 225 | playing clarinet | 325 | somersaulting |
| 26 | blowing nose | 126 | filling eyebrows | 226 | playing controller | 326 | spinning poi |
| 27 | blowing out candles | 127 | finger snapping | 227 | playing cricket | 327 | spray painting |
| 28 | bobsledding | 128 | fixing hair | 228 | playing cymbals | 328 | spraying |
| 29 | bookbinding | 129 | flipping pancake | 229 | playing didgeridoo | 329 | springboard diving |
| 30 | bouncing on trampoline | 130 | flying kite | 230 | playing drums | 330 | squat |
| 31 | bowling | 131 | folding clothes | 231 | playing flute | 331 | sticking tongue out |
| 32 | braiding hair | 132 | folding napkins | 232 | playing guitar | 332 | stomping grapes |
| 33 | breading or breadcrumbing | 133 | folding paper | 233 | playing harmonica | 333 | stretching arm |
| 34 | breakdancing | 134 | front raises | 234 | playing harp | 334 | stretching leg |
| 35 | brush painting | 135 | frying vegetables | 235 | playing ice hockey | 335 | strumming guitar |
| 36 | brushing hair | 136 | garbage collecting | 236 | playing keyboard | 336 | surfing crowd |
| 37 | brushing teeth | 137 | gargling | 237 | playing kickball | 337 | surfing water |
| 38 | building cabinet | 138 | getting a haircut | 238 | playing monopoly | 338 | sweeping floor |
| 39 | building shed | 139 | getting a tattoo | 239 | playing organ | 339 | swimming backstroke |
| 40 | bungee jumping | 140 | giving or receiving award | 240 | playing paintball | 340 | swimming breast stroke |
| 41 | busking | 141 | golf chipping | 241 | playing piano | 341 | swimming butterfly stroke |
| 42 | canoeing or kayaking | 142 | golf driving | 242 | playing poker | 342 | swing dancing |
| 43 | capoeira | 143 | golf putting | 243 | playing recorder | 343 | swinging legs |
| 44 | carrying baby | 144 | grinding meat | 244 | playing saxophone | 344 | swinging on something |
| 45 | cartwheeling | 145 | grooming dog | 245 | playing squash or racquetball | 345 | sword fighting |
| 46 | carving pumpkin | 146 | grooming horse | 246 | playing tennis | 346 | tai chi |
| 47 | catching fish | 147 | gymnastics tumbling | 247 | playing trombone | 347 | taking a shower |
| 48 | catching or throwing baseball | 148 | hammer throw | 248 | playing trumpet | 348 | tango dancing |
| 49 | catching or throwing frisbee | 149 | headbanging | 249 | playing ukulele | 349 | tap dancing |
| 50 | catching or throwing softball | 150 | headbutting | 250 | playing violin | 350 | tapping guitar |
| 51 | celebrating | 151 | high jump | 251 | playing volleyball | 351 | tapping pen |
| 52 | changing oil | 152 | high kick | 252 | playing xylophone | 352 | tasting beer |
| 53 | changing wheel | 153 | hitting baseball | 253 | pole vault | 353 | tasting food |
| 54 | checking tires | 154 | hockey stop | 254 | presenting weather forecast | 354 | testifying |
| 55 | cheerleading | 155 | holding snake | 255 | pull ups | 355 | texting |
| 56 | chopping wood | 156 | hopscotch | 256 | pumping fist | 356 | throwing axe |
| 57 | clapping | 157 | hoverboarding | 257 | pumping gas | 357 | throwing ball |
| 58 | clay pottery making | 158 | hugging | 258 | punching bag | 358 | throwing discus |
| 59 | clean and jerk | 159 | hula hooping | 259 | punching person (boxing) | 359 | tickling |
| 60 | cleaning floor | 160 | hurdling | 260 | push up | 360 | tobogganing |
| 61 | cleaning gutters | 161 | hurling (sport) | 261 | pushing car | 361 | tossing coin |
| 62 | cleaning pool | 162 | ice climbing | 262 | pushing cart | 362 | tossing salad |
| 63 | cleaning shoes | 163 | ice fishing | 263 | pushing wheelchair | 363 | training dog |
| 64 | cleaning toilet | 164 | ice skating | 264 | reading book | 364 | trapezing |
| 65 | cleaning windows | 165 | ironing | 265 | reading newspaper | 365 | trimming or shaving beard |
| 66 | climbing a rope | 166 | javelin throw | 266 | recording music | 366 | trimming trees |
| 67 | climbing ladder | 167 | jetskiing | 267 | riding a bike | 367 | triple jump |
| 68 | climbing tree | 168 | jogging | 268 | riding camel | 368 | tying bow tie |
| 69 | contact juggling | 169 | juggling balls | 269 | riding elephant | 369 | tying knot (not on a tie) |
| 70 | cooking chicken | 170 | juggling fire | 270 | riding mechanical bull | 370 | tying tie |
| 71 | cooking egg | 171 | juggling soccer ball | 271 | riding mountain bike | 371 | unboxing |
| 72 | cooking on campfire | 172 | jumping into pool | 272 | riding mule | 372 | unloading truck |
| 73 | cooking sausages | 173 | jumpstyle dancing | 273 | riding or walking with horse | 373 | using computer |
| 74 | counting money | 174 | kicking field goal | 274 | riding scooter | 374 | using remote controller (not gaming) |
| 75 | country line dancing | 175 | kicking soccer ball | 275 | riding unicycle | 375 | using segway |
| 76 | cracking neck | 176 | kissing | 276 | ripping paper | 376 | vault |
| 77 | crawling baby | 177 | kitesurfing | 277 | robot dancing | 377 | waiting in line |
| 78 | crossing river | 178 | knitting | 278 | rock climbing | 378 | walking the dog |
| 79 | crying | 179 | krumping | 279 | rock scissors paper | 379 | washing dishes |
| 80 | curling hair | 180 | laughing | 280 | roller skating | 380 | washing feet |
| 81 | cutting nails | 181 | laying bricks | 281 | running on treadmill | 381 | washing hair |
| 82 | cutting pineapple | 182 | long jump | 282 | sailing | 382 | washing hands |
| 83 | cutting watermelon | 183 | lunge | 283 | salsa dancing | 383 | water skiing |
| 84 | dancing ballet | 184 | making a cake | 284 | sanding floor | 384 | water sliding |
| 85 | dancing charleston | 185 | making a sandwich | 285 | scrambling eggs | 385 | watering plants |
| 86 | dancing gangnam style | 186 | making bed | 286 | scuba diving | 386 | waxing back |
| 87 | dancing macarena | 187 | making jewelry | 287 | setting table | 387 | waxing chest |
| 88 | deadlifting | 188 | making pizza | 288 | shaking hands | 388 | waxing eyebrows |
| 89 | decorating the christmas tree | 189 | making snowman | 289 | shaking head | 389 | waxing legs |
| 90 | digging | 190 | making sushi | 290 | sharpening knives | 390 | weaving basket |
| 91 | dining | 191 | making tea | 291 | sharpening pencil | 391 | welding |
| 92 | disc golfing | 192 | marching | 292 | shaving head | 392 | whistling |
| 93 | diving cliff | 193 | massaging back | 293 | shaving legs | 393 | windsurfing |
| 94 | dodgeball | 194 | massaging feet | 294 | shearing sheep | 394 | wrapping present |
| 95 | doing aerobics | 195 | massaging legs | 295 | shining shoes | 395 | wrestling |
| 96 | doing laundry | 196 | massaging person's head | 296 | shooting basketball | 396 | writing |
| 97 | doing nails | 197 | milking cow | 297 | shooting goal (soccer) | 397 | yawning |
| 98 | drawing | 198 | mopping floor | 298 | shot put | 398 | yoga |
| 99 | dribbling basketball | 199 | motorcycling | 299 | shoveling snow | 399 | zumba |

Supplementary Table 9. Top 100 Radiomics Features from SVM-RBF

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Features | Rank | Features |
| 1 | original\_firstorder\_Energy | 51 | original\_shape\_LeastAxisLength |
| 2 | original\_glszm\_LargeAreaHighGrayLevelEmphasis | 52 | original\_glcm\_DifferenceVariance |
| 3 | original\_shape\_MeshVolume | 53 | original\_gldm\_DependenceVariance |
| 4 | original\_glcm\_ClusterProminence | 54 | original\_glcm\_JointAverage |
| 5 | original\_glszm\_LargeAreaEmphasis | 55 | original\_firstorder\_Kurtosis |
| 6 | original\_glszm\_ZoneVariance | 56 | original\_ngtdm\_Busyness |
| 7 | original\_firstorder\_Variance | 57 | original\_ngtdm\_Strength |
| 8 | original\_shape\_SurfaceArea | 58 | original\_glcm\_DifferenceAverage |
| 9 | original\_glrlm\_RunLengthNonUniformity | 59 | original\_glcm\_JointEntropy |
| 10 | original\_gldm\_LargeDependenceHighGrayLevelEmphasis | 60 | original\_firstorder\_Entropy |
| 11 | original\_gldm\_GrayLevelNonUniformity | 61 | original\_glcm\_SumEntropy |
| 12 | original\_glrlm\_GrayLevelNonUniformity | 62 | original\_glcm\_DifferenceEntropy |
| 13 | original\_ngtdm\_Complexity | 63 | original\_glrlm\_LongRunEmphasis |
| 14 | original\_glcm\_ClusterShade | 64 | original\_firstorder\_Skewness |
| 15 | original\_gldm\_DependenceNonUniformity | 65 | original\_glrlm\_RunEntropy |
| 16 | original\_glszm\_SizeZoneNonUniformity | 66 | original\_gldm\_LargeDependenceLowGrayLevelEmphasis |
| 17 | original\_firstorder\_10Percentile | 67 | original\_glrlm\_RunVariance |
| 18 | original\_firstorder\_Minimum | 68 | original\_ngtdm\_Contrast |
| 19 | original\_glcm\_Autocorrelation | 69 | original\_glszm\_ZonePercentage |
| 20 | original\_gldm\_HighGrayLevelEmphasis | 70 | original\_gldm\_SmallDependenceEmphasis |
| 21 | original\_glrlm\_ShortRunHighGrayLevelEmphasis | 71 | original\_glcm\_Idm |
| 22 | original\_glrlm\_HighGrayLevelRunEmphasis | 72 | original\_glcm\_Imc2 |
| 23 | original\_glszm\_LargeAreaLowGrayLevelEmphasis | 73 | original\_glcm\_Id |
| 24 | original\_glszm\_HighGrayLevelZoneEmphasis | 74 | original\_glrlm\_RunLengthNonUniformityNormalized |
| 25 | original\_firstorder\_Range | 75 | original\_shape\_SurfaceVolumeRatio |
| 26 | original\_firstorder\_InterquartileRange | 76 | original\_glcm\_InverseVariance |
| 27 | original\_glszm\_SmallAreaHighGrayLevelEmphasis | 77 | original\_glrlm\_RunPercentage |
| 28 | original\_firstorder\_Mean | 78 | original\_gldm\_DependenceNonUniformityNormalized |
| 29 | original\_gldm\_SmallDependenceHighGrayLevelEmphasis | 79 | original\_glcm\_Imc1 |
| 30 | original\_firstorder\_Median | 80 | original\_firstorder\_Uniformity |
| 31 | original\_firstorder\_RootMeanSquared | 81 | original\_glszm\_SizeZoneNonUniformityNormalized |
| 32 | original\_glrlm\_LongRunHighGrayLevelEmphasis | 82 | original\_glrlm\_ShortRunEmphasis |
| 33 | original\_glcm\_ClusterTendency | 83 | original\_gldm\_DependenceEntropy |
| 34 | original\_glszm\_GrayLevelNonUniformity | 84 | original\_glszm\_ZoneEntropy |
| 35 | original\_firstorder\_Maximum | 85 | original\_glcm\_MaximumProbability |
| 36 | original\_firstorder\_MeanAbsoluteDeviation | 86 | original\_glrlm\_GrayLevelNonUniformityNormalized |
| 37 | original\_firstorder\_RobustMeanAbsoluteDeviation | 87 | original\_glszm\_SmallAreaEmphasis |
| 38 | original\_shape\_Maximum3DDiameter | 88 | original\_shape\_Sphericity |
| 39 | original\_gldm\_LargeDependenceEmphasis | 89 | original\_glcm\_Idn |
| 40 | original\_shape\_MajorAxisLength | 90 | original\_glcm\_JointEnergy |
| 41 | original\_glcm\_Contrast | 91 | original\_shape\_Flatness |
| 42 | original\_gldm\_GrayLevelVariance | 92 | original\_glszm\_GrayLevelNonUniformityNormalized |
| 43 | original\_glrlm\_GrayLevelVariance | 93 | original\_shape\_Elongation |
| 44 | original\_glcm\_SumSquares | 94 | original\_glcm\_Idmn |
| 45 | original\_shape\_Maximum2DDiameterRow | 95 | original\_glszm\_LowGrayLevelZoneEmphasis |
| 46 | original\_shape\_Maximum2DDiameterSlice | 96 | original\_glcm\_Correlation |
| 47 | original\_shape\_Maximum2DDiameterColumn | 97 | original\_glszm\_SmallAreaLowGrayLevelEmphasis |
| 48 | original\_firstorder\_90Percentile | 98 | original\_glrlm\_LongRunLowGrayLevelEmphasis |
| 49 | original\_glszm\_GrayLevelVariance | 99 | original\_ngtdm\_Coarseness |
| 50 | original\_shape\_MinorAxisLength | 100 | original\_gldm\_SmallDependenceLowGrayLevelEmphasis |

Supplementary Table 10. Top 100 Deep Features from SVM-RBF

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Features | Rank | Features |
| 1 | weaving basket | 51 | playing bass guitar |
| 2 | making a cake | 52 | blowing leaves |
| 3 | hockey stop | 53 | playing controller |
| 4 | knitting | 54 | playing badminton |
| 5 | making jewelry | 55 | parkour |
| 6 | hammer throw | 56 | drinking |
| 7 | braiding hair | 57 | playing squash or racquetball |
| 8 | curling hair | 58 | pole vault |
| 9 | playing cricket | 59 | tying knot (not on a tie) |
| 10 | making tea | 60 | dining |
| 11 | ice skating | 61 | cleaning shoes |
| 12 | getting a haircut | 62 | playing ice hockey |
| 13 | somersaulting | 63 | doing laundry |
| 14 | hitting baseball | 64 | eating spaghetti |
| 15 | carving pumpkin | 65 | shot put |
| 16 | strumming guitar | 66 | playing volleyball |
| 17 | using computer | 67 | decorating the christmas tree |
| 18 | watering plants | 68 | passing American football (not in game) |
| 19 | arranging flowers | 69 | building shed |
| 20 | springboard diving | 70 | stomping grapes |
| 21 | baking cookies | 71 | catching or throwing frisbee |
| 22 | drawing | 72 | peeling apples |
| 23 | bartending | 73 | folding clothes |
| 24 | drop kicking | 74 | bouncing on trampoline |
| 25 | changing wheel | 75 | shooting goal (soccer) |
| 26 | changing oil | 76 | catching or throwing softball |
| 27 | barbequing | 77 | surfing water |
| 28 | shoveling snow | 78 | hurling (sport) |
| 29 | eating cake | 79 | juggling balls |
| 30 | diving cliff | 80 | throwing ball |
| 31 | javelin throw | 81 | plastering |
| 32 | cartwheeling | 82 | dodgeball |
| 33 | tossing salad | 83 | cracking neck |
| 34 | vault | 84 | rock climbing |
| 35 | milking cow | 85 | shaving head |
| 36 | walking the dog | 86 | using remote controller (not gaming) |
| 37 | gymnastics tumbling | 87 | spray painting |
| 38 | getting a tattoo | 88 | trapezing |
| 39 | throwing axe | 89 | setting table |
| 40 | garbage collecting | 90 | skiing (not slalom or crosscountry) |
| 41 | assembling computer | 91 | headbutting |
| 42 | playing tennis | 92 | clapping |
| 43 | grinding meat | 93 | jogging |
| 44 | training dog | 94 | brush painting |
| 45 | golf driving | 95 | cooking sausages |
| 46 | taking a shower | 96 | massaging back |
| 47 | snowboarding | 97 | waxing chest |
| 48 | holding snake | 98 | juggling soccer ball |
| 49 | checking tires | 99 | playing chess |
| 50 | shining shoes | 100 | snatch weight lifting |

Supplementary Table 11. Pearson Correlation Coefficient (PCC) of Top 100 Deep Features with Tumour Volume

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Deep Features Label | PCC in OPC | PCC in H&N 1 | PCC in LUNG 1 | PCC in LUNG 4 |
| weaving basket | 0.271 | 0.157 | 0.397 | 0.298 |
| making a cake | 0.252 | 0.225 | 0.414 | 0.362 |
| hockey stop | 0.304 | 0.378 | 0.469 | 0.495 |
| knitting | 0.198 | 0.220 | 0.312 | 0.316 |
| making jewelry | 0.184 | 0.290 | 0.268 | 0.266 |
| hammer throw | 0.059 | 0.063 | 0.462 | 0.315 |
| braiding hair | 0.385 | 0.324 | 0.482 | 0.366 |
| curling hair | 0.352 | 0.324 | 0.429 | 0.382 |
| playing cricket | 0.086 | 0.164 | 0.447 | 0.326 |
| making tea | 0.045 | 0.022 | 0.260 | 0.233 |
| ice skating | 0.001 | 0.221 | 0.596 | 0.279 |
| getting a haircut | 0.486 | 0.410 | 0.507 | 0.336 |
| somersaulting | 0.312 | 0.351 | 0.564 | 0.377 |
| hitting baseball | 0.052 | 0.016 | 0.362 | 0.285 |
| carving pumpkin | 0.352 | 0.325 | 0.553 | 0.438 |
| strumming guitar | 0.054 | 0.290 | 0.488 | 0.315 |
| using computer | 0.351 | 0.240 | 0.364 | 0.318 |
| watering plants | 0.040 | 0.093 | 0.117 | 0.109 |
| arranging flowers | 0.321 | 0.310 | 0.419 | 0.376 |
| springboard diving | 0.056 | 0.393 | 0.456 | 0.198 |
| baking cookies | 0.064 | 0.224 | 0.342 | 0.253 |
| drawing | 0.316 | 0.252 | 0.296 | 0.069 |
| bartending | 0.196 | 0.080 | 0.318 | 0.284 |
| drop kicking | 0.381 | 0.296 | 0.527 | 0.380 |
| changing wheel | 0.033 | 0.101 | 0.371 | 0.049 |
| changing oil | 0.193 | 0.166 | 0.402 | 0.217 |
| barbequing | 0.088 | 0.076 | 0.235 | 0.193 |
| shoveling snow | 0.133 | 0.102 | 0.111 | 0.010 |
| eating cake | 0.273 | 0.129 | 0.244 | 0.361 |
| diving cliff | 0.284 | 0.207 | 0.295 | 0.011 |
| javelin throw | 0.235 | 0.063 | 0.441 | 0.412 |
| cartwheeling | 0.374 | 0.182 | 0.545 | 0.411 |
| tossing salad | 0.163 | 0.071 | 0.320 | 0.347 |
| vault | 0.231 | 0.017 | 0.159 | 0.015 |
| milking cow | 0.286 | 0.145 | 0.498 | 0.433 |
| walking the dog | 0.146 | 0.333 | 0.290 | 0.246 |
| gymnastics tumbling | 0.091 | 0.115 | 0.369 | 0.320 |
| getting a tattoo | 0.530 | 0.256 | 0.532 | 0.437 |
| throwing axe | 0.189 | 0.002 | 0.212 | 0.238 |
| garbage collecting | 0.236 | 0.021 | 0.151 | 0.250 |
| assembling computer | 0.393 | 0.225 | 0.359 | 0.301 |
| playing tennis | 0.227 | 0.281 | 0.526 | 0.612 |
| grinding meat | 0.369 | 0.182 | 0.344 | 0.377 |
| training dog | 0.235 | 0.336 | 0.244 | 0.330 |
| golf driving | 0.344 | 0.158 | 0.489 | 0.399 |
| taking a shower | 0.264 | 0.350 | 0.227 | 0.133 |
| snowboarding | 0.005 | 0.163 | 0.245 | 0.224 |
| holding snake | 0.027 | 0.117 | 0.140 | 0.071 |
| checking tires | 0.228 | 0.093 | 0.215 | 0.079 |
| shining shoes | 0.272 | 0.293 | 0.346 | 0.070 |
| weaving basket | 0.154 | 0.030 | 0.330 | 0.231 |
| making a cake | 0.070 | 0.286 | 0.271 | 0.132 |
| hockey stop | 0.064 | 0.194 | 0.107 | 0.222 |
| knitting | 0.222 | 0.266 | 0.519 | 0.573 |
| making jewelry | 0.284 | 0.292 | 0.377 | 0.354 |
| hammer throw | 0.250 | 0.213 | 0.334 | 0.302 |
| braiding hair | 0.186 | 0.333 | 0.503 | 0.523 |
| curling hair | 0.113 | 0.049 | 0.299 | 0.206 |
| playing cricket | 0.089 | 0.027 | 0.051 | 0.114 |
| making tea | 0.042 | 0.051 | 0.276 | 0.362 |
| ice skating | 0.073 | 0.060 | 0.080 | 0.167 |
| getting a haircut | 0.123 | 0.221 | 0.454 | 0.225 |
| somersaulting | 0.111 | 0.080 | 0.075 | 0.052 |
| hitting baseball | 0.335 | 0.249 | 0.462 | 0.382 |
| carving pumpkin | 0.038 | 0.122 | 0.389 | 0.327 |
| strumming guitar | 0.001 | 0.142 | 0.477 | 0.303 |
| using computer | 0.240 | 0.228 | 0.222 | 0.323 |
| watering plants | 0.294 | 0.177 | 0.422 | 0.370 |
| arranging flowers | 0.058 | 0.164 | 0.238 | 0.142 |
| springboard diving | 0.140 | 0.075 | 0.095 | 0.138 |
| baking cookies | 0.498 | 0.378 | 0.496 | 0.583 |
| drawing | 0.447 | 0.417 | 0.485 | 0.380 |
| bartending | 0.016 | 0.163 | 0.091 | 0.239 |
| drop kicking | 0.041 | 0.220 | 0.494 | 0.402 |
| changing wheel | 0.318 | 0.157 | 0.388 | 0.391 |
| changing oil | 0.094 | 0.101 | 0.372 | 0.320 |
| barbequing | 0.210 | 0.389 | 0.293 | 0.166 |
| shoveling snow | 0.335 | 0.252 | 0.406 | 0.329 |
| eating cake | 0.318 | 0.027 | 0.245 | 0.116 |
| diving cliff | 0.100 | 0.062 | 0.445 | 0.333 |
| javelin throw | 0.065 | 0.149 | 0.329 | 0.255 |
| cartwheeling | 0.016 | 0.098 | 0.354 | 0.344 |
| tossing salad | 0.035 | 0.009 | 0.164 | 0.164 |
| vault | 0.024 | 0.207 | 0.127 | 0.036 |
| milking cow | 0.509 | 0.318 | 0.446 | 0.445 |
| walking the dog | 0.059 | 0.199 | 0.122 | 0.257 |
| gymnastics tumbling | 0.041 | 0.186 | 0.239 | 0.024 |
| getting a tattoo | 0.200 | 0.014 | 0.309 | 0.217 |
| throwing axe | 0.151 | 0.045 | 0.004 | 0.093 |
| garbage collecting | 0.147 | 0.043 | 0.229 | 0.144 |
| assembling computer | 0.215 | 0.104 | 0.193 | 0.131 |
| playing tennis | 0.144 | 0.296 | 0.221 | 0.288 |
| grinding meat | 0.164 | 0.241 | 0.338 | 0.400 |
| training dog | 0.409 | 0.314 | 0.366 | 0.238 |
| golf driving | 0.192 | 0.059 | 0.195 | 0.129 |
| taking a shower | 0.092 | 0.002 | 0.170 | 0.096 |
| snowboarding | 0.315 | 0.156 | 0.035 | 0.115 |
| holding snake | 0.156 | 0.037 | 0.338 | 0.396 |
| checking tires | 0.463 | 0.295 | 0.273 | 0.221 |
| shining shoes | 0.023 | 0.065 | 0.018 | 0.041 |

Supplementary Table 12. Pearson Correlation Coefficient (PCC) of Top 100 Deep Features with TNM Staging

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Deep Features | PCC in OPC | PCC in H&N 1 | PCC in LUNG 1 | PCC in LUNG 4 |
| weaving basket | 0.095 | 0.182 | 0.177 | 0.205 |
| making a cake | 0.032 | 0.166 | 0.155 | 0.206 |
| hockey stop | 0.095 | 0.096 | 0.165 | 0.143 |
| knitting | 0.064 | 0.444 | 0.126 | 0.232 |
| making jewelry | 0.086 | 0.278 | 0.032 | 0.131 |
| hammer throw | 0.086 | 0.116 | 0.253 | 0.038 |
| braiding hair | 0.113 | 0.490 | 0.165 | 0.172 |
| curling hair | 0.113 | 0.514 | 0.156 | 0.211 |
| playing cricket | 0.076 | 0.111 | 0.227 | 0.078 |
| making tea | 0.055 | 0.064 | 0.093 | 0.228 |
| ice skating | 0.103 | 0.062 | 0.194 | 0.238 |
| getting a haircut | 0.105 | 0.385 | 0.194 | 0.173 |
| somersaulting | 0.089 | 0.298 | 0.223 | 0.080 |
| hitting baseball | 0.021 | 0.041 | 0.152 | 0.041 |
| carving pumpkin | 0.093 | 0.291 | 0.211 | 0.142 |
| strumming guitar | 0.012 | 0.297 | 0.187 | 0.073 |
| using computer | 0.079 | 0.304 | 0.167 | 0.122 |
| watering plants | 0.075 | 0.166 | 0.070 | 0.179 |
| arranging flowers | 0.083 | 0.305 | 0.114 | 0.121 |
| springboard diving | 0.085 | 0.278 | 0.143 | 0.001 |
| baking cookies | 0.088 | 0.152 | 0.097 | 0.061 |
| drawing | 0.085 | 0.420 | 0.115 | 0.122 |
| bartending | 0.050 | 0.273 | 0.134 | 0.103 |
| drop kicking | 0.081 | 0.246 | 0.242 | 0.141 |
| changing wheel | 0.050 | 0.083 | 0.244 | 0.097 |
| changing oil | 0.102 | 0.156 | 0.262 | 0.050 |
| barbequing | 0.087 | 0.195 | 0.201 | 0.133 |
| shoveling snow | 0.095 | 0.125 | 0.005 | 0.036 |
| eating cake | 0.095 | 0.152 | 0.011 | 0.194 |
| diving cliff | 0.095 | 0.051 | 0.151 | 0.039 |
| javelin throw | 0.080 | 0.323 | 0.118 | 0.140 |
| cartwheeling | 0.054 | 0.125 | 0.165 | 0.166 |
| tossing salad | 0.098 | 0.168 | 0.109 | 0.225 |
| vault | 0.128 | 0.060 | 0.115 | 0.134 |
| milking cow | 0.013 | 0.135 | 0.182 | 0.139 |
| walking the dog | 0.116 | 0.413 | 0.060 | 0.028 |
| gymnastics tumbling | 0.104 | 0.005 | 0.124 | 0.197 |
| getting a tattoo | 0.128 | 0.465 | 0.194 | 0.075 |
| throwing axe | 0.059 | 0.085 | 0.030 | 0.075 |
| garbage collecting | 0.111 | 0.297 | 0.113 | 0.189 |
| assembling computer | 0.121 | 0.253 | 0.201 | 0.232 |
| playing tennis | 0.113 | 0.347 | 0.062 | 0.103 |
| grinding meat | 0.114 | 0.064 | 0.154 | 0.222 |
| training dog | 0.104 | 0.150 | 0.051 | 0.065 |
| golf driving | 0.075 | 0.013 | 0.171 | 0.179 |
| taking a shower | 0.118 | 0.323 | 0.067 | 0.119 |
| snowboarding | 0.137 | 0.064 | 0.077 | 0.061 |
| holding snake | 0.064 | 0.083 | 0.010 | 0.114 |
| checking tires | 0.107 | 0.065 | 0.243 | 0.052 |
| shining shoes | 0.074 | 0.224 | 0.072 | 0.128 |
| weaving basket | 0.150 | 0.040 | 0.141 | 0.019 |
| making a cake | 0.126 | 0.218 | 0.111 | 0.027 |
| hockey stop | 0.063 | 0.022 | 0.022 | 0.068 |
| knitting | 0.069 | 0.429 | 0.150 | 0.238 |
| making jewelry | 0.007 | 0.226 | 0.158 | 0.051 |
| hammer throw | 0.059 | 0.208 | 0.056 | 0.278 |
| braiding hair | 0.172 | 0.129 | 0.188 | 0.049 |
| curling hair | 0.104 | 0.068 | 0.133 | 0.096 |
| playing cricket | 0.032 | 0.182 | 0.087 | 0.051 |
| making tea | 0.058 | 0.108 | 0.090 | 0.128 |
| ice skating | 0.052 | 0.125 | 0.052 | 0.024 |
| getting a haircut | 0.055 | 0.014 | 0.202 | 0.047 |
| somersaulting | 0.063 | 0.058 | 0.093 | 0.136 |
| hitting baseball | 0.033 | 0.207 | 0.208 | 0.211 |
| carving pumpkin | 0.022 | 0.159 | 0.257 | 0.062 |
| strumming guitar | 0.034 | 0.281 | 0.274 | 0.108 |
| using computer | 0.067 | 0.132 | 0.123 | 0.049 |
| watering plants | 0.124 | 0.186 | 0.229 | 0.053 |
| arranging flowers | 0.116 | 0.136 | 0.008 | 0.112 |
| springboard diving | 0.110 | 0.316 | 0.008 | 0.086 |
| baking cookies | 0.049 | 0.373 | 0.087 | 0.053 |
| drawing | 0.084 | 0.296 | 0.214 | 0.146 |
| bartending | 0.053 | 0.389 | 0.032 | 0.121 |
| drop kicking | 0.051 | 0.461 | 0.174 | 0.074 |
| changing wheel | 0.084 | 0.141 | 0.146 | 0.010 |
| changing oil | 0.001 | 0.067 | 0.169 | 0.104 |
| barbequing | 0.061 | 0.168 | 0.044 | 0.037 |
| shoveling snow | 0.092 | 0.336 | 0.115 | 0.019 |
| eating cake | 0.138 | 0.289 | 0.193 | 0.084 |
| diving cliff | 0.043 | 0.274 | 0.237 | 0.101 |
| javelin throw | 0.097 | 0.097 | 0.167 | 0.039 |
| cartwheeling | 0.043 | 0.108 | 0.195 | 0.098 |
| tossing salad | 0.001 | 0.339 | 0.064 | 0.043 |
| vault | 0.020 | 0.237 | 0.158 | 0.147 |
| milking cow | 0.064 | 0.291 | 0.124 | 0.220 |
| walking the dog | 0.018 | 0.141 | 0.041 | 0.136 |
| gymnastics tumbling | 0.074 | 0.136 | 0.149 | 0.160 |
| getting a tattoo | 0.111 | 0.271 | 0.105 | 0.142 |
| throwing axe | 0.045 | 0.002 | 0.026 | 0.000 |
| garbage collecting | 0.036 | 0.083 | 0.062 | 0.017 |
| assembling computer | 0.041 | 0.135 | 0.070 | 0.119 |
| playing tennis | 0.040 | 0.203 | 0.023 | 0.048 |
| grinding meat | 0.034 | 0.399 | 0.065 | 0.110 |
| training dog | 0.079 | 0.530 | 0.154 | 0.063 |
| golf driving | 0.019 | 0.126 | 0.179 | 0.151 |
| taking a shower | 0.048 | 0.097 | 0.045 | 0.161 |
| snowboarding | 0.008 | 0.323 | 0.108 | 0.161 |
| holding snake | 0.042 | 0.264 | 0.165 | 0.202 |
| checking tires | 0.136 | 0.314 | 0.052 | 0.034 |
| shining shoes | 0.073 | 0.220 | 0.010 | 0.144 |