

# ONCO-RADS in 10 cases

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# Oncologically Relevant Findings Reporting and Data System (ONCO-RADS): Guidelines for the Acquisition, Interpretation, and Reporting of Whole-Body MRI for Cancer Screening

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Conflicts of interest are listed at the end of this article.

## 1. NO RADIATION

Histotype	N° of pts		Rule out			Rule in		
			SE	NPV	-LR	SP	PPV	+LR
Bone M+ (Prostate) <sup>1</sup>	402	MRI	95%	/	/	96%	/	/
	1012	PET	87%	/	/	97%	/	/
Bone & soft tissue M+ (any cancer) <sup>2</sup>	1070	MRI	86%	/	0.15	97%	/	32.3
	1070	PET	85%	/	0.16	96%	/	22.7
All cancers (primary & mets) <sup>3</sup>	1067	MRI	90%	96%	0.12	95%	89%	11.8
		PET	89%	/	0.07	97%	/	26.8

WB-MRI → False positive rate → 4.6%

WB-MRI → False negative rate → 10.2%

1. Shen G, et al. Skeletal Radiol. 2014 Nov;43(11):1503-13.
2. Xu GZ, et al. Ann Oncol. 2013 Jan;24(1):96-101.
3. Li B, et al. Eur J Radiol. 2014 Feb;83(2):338-44

## 2. WB-MRI can detect the most common cancers

*Top-ten 2023*



- The «Big Three» (Screened already)

1. Prostate / Breast
2. Lung
3. Colon & Rectum



- Other common ca. (Not screened)

- Urinary bladder
- Kidney, NHL
- Pancreas, etc.

**Estimated New Cases**

			Males	Females			
Prostate	288,300	29%			Breast	297,790	31%
Lung & bronchus	117,550	12%			Lung & bronchus	120,790	13%
Colon & rectum	81,860	8%			Colon & rectum	71,160	8%
Urinary bladder	62,420	6%			Uterine corpus	66,200	7%
Melanoma of the skin	58,120	6%			Melanoma of the skin	39,490	4%
Kidney & renal pelvis	52,360	5%			Non-Hodgkin lymphoma	35,670	4%
Non-Hodgkin lymphoma	44,880	4%			Thyroid	31,180	3%
Oral cavity & pharynx	39,290	4%			Pancreas	30,920	3%
Leukemia	35,670	4%			Kidney & renal pelvis	29,440	3%
Pancreas	33,130	3%			Leukemia	23,940	3%
<b>All Sites</b>	<b>1,010,310</b>	<b>100%</b>			<b>All Sites</b>	<b>948,000</b>	<b>100%</b>

**Estimated Deaths**

			Males	Females			
Lung & bronchus	67,160	21%			Lung & bronchus	59,910	21%
Prostate	34,700	11%			Breast	43,170	15%
Colon & rectum	28,470	9%			Colon & rectum	24,080	8%
Pancreas	26,620	8%			Pancreas	23,930	8%
Liver & intrahepatic bile duct	19,000	6%			Ovary	13,270	5%
Leukemia	13,900	4%			Uterine corpus	13,030	5%
Esophagus	12,920	4%			Liver & intrahepatic bile duct	10,380	4%
Urinary bladder	12,160	4%			Leukemia	9,810	3%
Non-Hodgkin lymphoma	11,780	4%			Non-Hodgkin lymphoma	8,400	3%
Brain & other nervous system	11,020	3%			Brain & other nervous system	7,970	3%
<b>All Sites</b>	<b>322,080</b>	<b>100%</b>			<b>All Sites</b>	<b>287,740</b>	<b>100%</b>

### 3. WB-MRI is recommended for cancer screening in the following *cancer predisposition syndromes*

*\*Same or separate sitting*

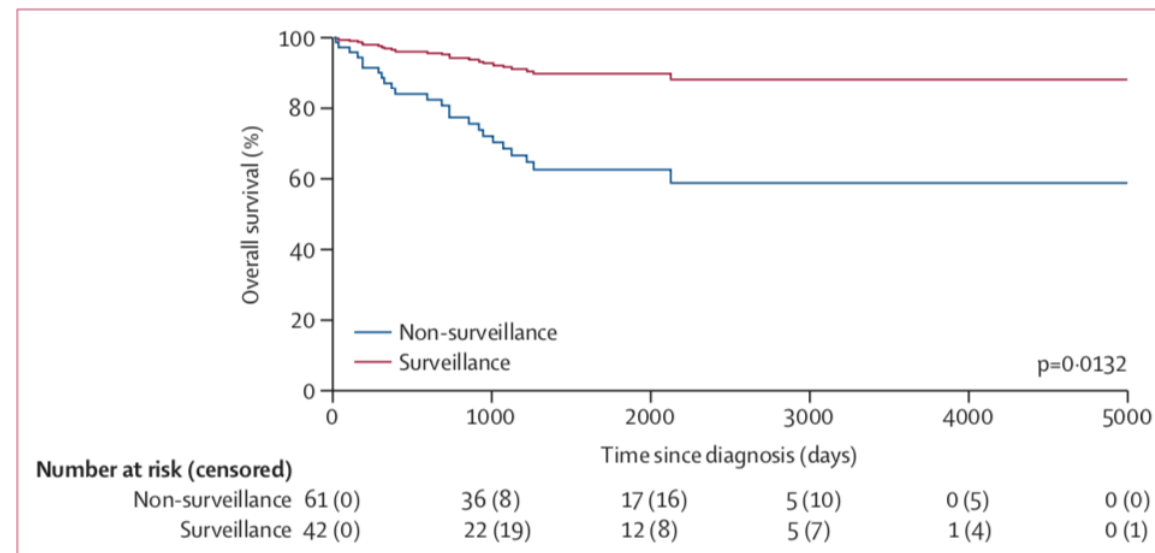
Syndromes	Age	Most common cancers	Anatomical coverage
Li-Fraumeni syndrome (LFS) <sup>1-8</sup>	Any (Annual)	Sarcomas & osteosarcomas, premenopausal breast cancer, adrenocortical carcinomas, central nervous system tumours ( <i>Astrocytomas, glioblastomas, medulloblastomas, choroid plexus carcinomas</i> )	Vertex to the heels ( <i>Contrast-enhanced brain sequences*, Breast MRI*</i> )
Hereditary Paraganglioma-Pheochromocytoma syndromes (HPP) <sup>9-10</sup>	From 6-8yy (every 2 years)	Paraganglioma, pheochromocytoma ( <i>&gt;Renal cancers, GIST, pituitary adenomas, etc.</i> )	Skull base to mid-thighs
Constitutional mismatch repair deficiency syndrome (CMMRD) <sup>11-14</sup>	From 6-8yy (Annual)	Haematological tumours, brain/central nervous system tumours, colorectal and other intestinal tract cancers	Vertex to heels ( <i>Contrast-enhanced brain sequences*</i> )
Hereditary retinoblastoma <sup>15</sup>	From 8yy (Annual)	Retinoblastoma ( <i>&gt;Sarcomas &amp; osteosarcomas, melanoma, lung cancer, SCC, brain tumours, urogenital &amp; GI tumours</i> )	Vertex to mid-thighs ( <i>Contrast-enhanced brain sequences*</i> )

- |                        |                                     |                            |                      |
|------------------------|-------------------------------------|----------------------------|----------------------|
| 1. TORONTO protocol    | 5. GENTURIS guidelines              | 9. Rednam SP et al         | 13. C4CMMRD          |
| 2. ESMO guidelines     | 6. UKCGG Consensus Group guidelines | 10. Garcia-Carbonero et al | 14. IRRD consortium  |
| 3. ESO-ESMO guidelines | 7. Kumamoto et al.                  | 11. AACR                   | 15. Greer MC, et al. |
| 4. NCCN guidelines     | 8. Australian Recommendations       | 12. US task force          |                      |

# Survival benefit for individuals with LFS undergoing surveillance<sup>1</sup>

	Individuals	Cancers	Detection rate*
Ballinger ML et al. (2017)	578	39	<b>6.74 %</b>
Mai PL et al. (2017)	116	5	<b>4.3 %</b>
Villani A et al. (2016)	59	19	<b>32 %</b>
Paixão et al. (2018)	59	2	<b>3,4%</b>
Bojadzieva J et al. (2018)	53	8	<b>15.1 %</b>
Saya S et al. (2017)	44	6	<b>13.6 %</b>
Tewattanarat N. et al. (2022)	31	7	<b>22,6%</b>

\*On initial screening



**Figure 1: Overall survival in the surveillance and non-surveillance groups**  
Number at risk refers to the number of tumours, not individuals.

\*Surveillance protocol included physical examination and frequent biochemical and imaging studies (WB-MRI, brain MRI, breast MRI, mammography, abdominal and pelvic ultrasound, and colonoscopy)

1. Villani A et al., Lancet Oncol. 2016 Sep;17(9):1295-305.

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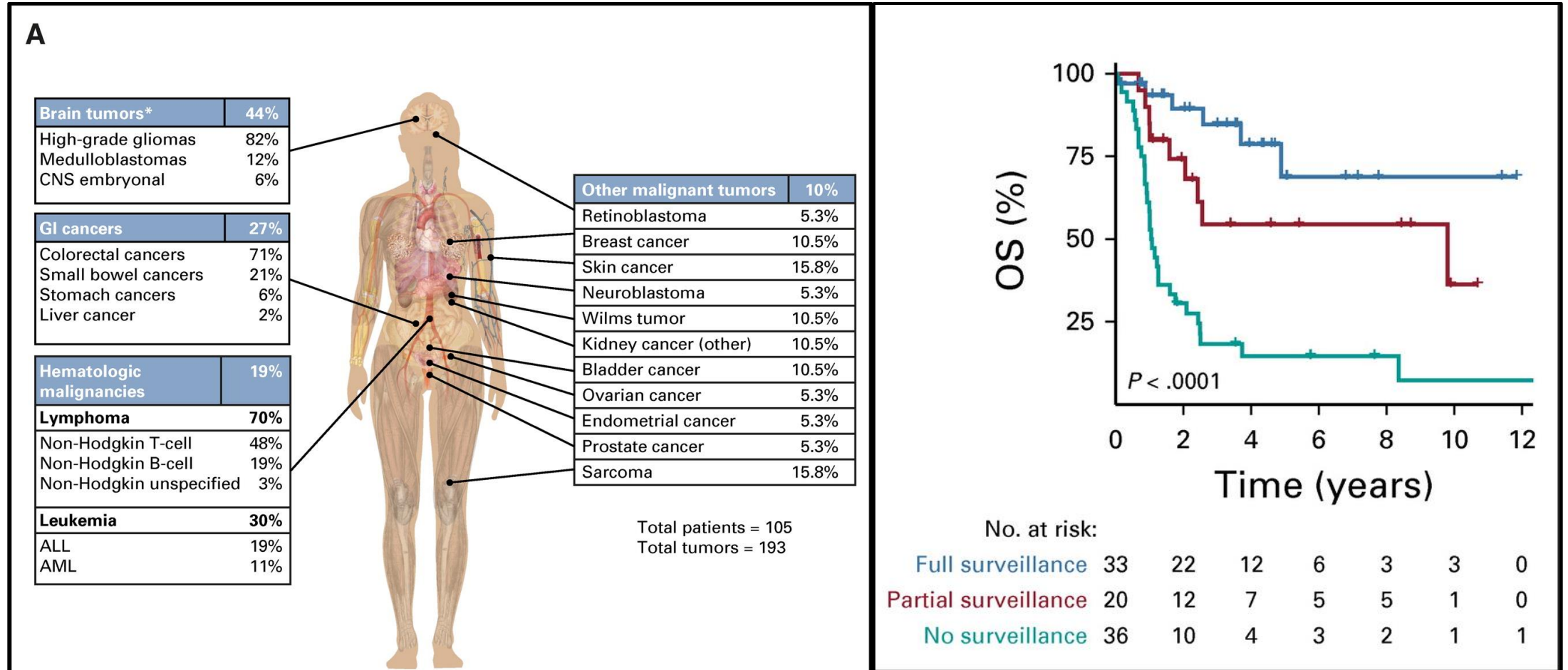
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Hereditary Paranglioma-Pheochromocytoma syndromes (HPP) <sup>9-10</sup>	From 6-8yy (every 2 years)	Paranglioma, pheochromocytoma (>Renal cancers, GIST, pituitary adenomas, etc.)	Skull base to mid-thighs
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# Survival benefit for individuals with CMMRD undergoing surveillance<sup>1</sup>



1. Durno C et al. J Clin Oncol. 2021 Sep 1;39(25):2779-2790

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## 4. WB-MRI is increasingly used for Cancer Screening *Individuals of the general population*

- **Advantages<sup>1-22</sup>**
  - Offered in «health checks»
  - High sensitivity
  - Reasonable examination times
  - No side effects

*NO RADIATION - NO INJECTION*

1. Goehde SC, et al. Am J Roentgenol, 2005; 184: 598–611
2. Baumgart D, et al. Herz, 2007; 32: 387–94
3. Lo GG, et al. Hong Kong Med J, 2008; 14: 90–96
4. Morin SHX, et al. Eur J Radiol. Elsevier; 2009;72(3):529–533.
5. Takahara T, et al. Eur Radiol 2010 Jun;20(6):1366-73.
6. Laible M, et al. Insights Imaging. Springer; 2012;3(5):485–493.
7. Hegenscheid K, et al.. Eur Radiol, 2013; 23: 816–26
8. Cieszanowski A, et al. PLoS One. 2014 Sep 26;9(9)
9. Bamberg F, et al. Radiology. 2015; 277: 206-20
10. Tarnoki DL, et al. Radiol Oncol, 2015; 49(1): 10–16
11. Ulus S, et al. Pol J Radiol. 2016 Aug 30;81:407-14
12. Saya S, et al. Fam Cancer. Springer; 2017;16(3):433–440.
13. Perkins BA, et al. Proc Natl Acad Sci USA 2018 Apr 3;115(14):3686-3691.
14. Lee SY, et al. PLoS One. 2018;13(11):e0206681.
15. Petralia G, et al. Magn Reson Imaging Clin N Am. 2018 Nov;26(4):495-507.
16. Petralia G, et al. Radiol Med. 2018 Nov 14.
17. Kwee RM, et al. J Magn Reson Imaging. 2019 Nov;50(5):1489-1503.
18. Zugni F, et al. Cancer Imaging 2020;20(1):34.
19. Hou YCC, et al. Proc Natl Acad Sci U S A 2020;117(6):3053–3062.
20. Petralia G, et al. Radiol Med. 2021 Nov;126(11):1434-1450.
21. Basar Y. Et al. Eur J Radiol. 2021 Apr;137:109584.
22. Ji Na Kim et al. Eur J Radiol. 2022; 110239

# Evidence for the use of WB-MRI in the general population

- Challenges

- Cancer → About 2%

- How to *maximise potential*?

- Oncological expertise in multi-organ evaluations

- Incidental findings → Up to 99%

- How to *minimise harm*?

- Trust a negative WB-MRI and do not over-investigate

- » High NPV & low prevalence of cancer

	Subjects	Cancer	Incidental findings
Bamberg F et al. (2015)	30,000	Ongoing	Ongoing
Hegenscheid K et al. (2013)	2,500	5,9%*	/
Baumgart D et al. (2007)	1007	<b>0.44 %</b>	/
Cieszanowski A et al. (2014)	666	<b>1.05 %</b>	<b>99%</b>
Basar Y et al. (2021)	576	<b>2.6 %</b>	/
Goede SC et al. (2005)	298	<b>0.33 %</b>	/
Lee SY et al. (2018)	229	<b>0.8%</b>	<b>93%</b>
Lo GG et al. (2008)	132	<b>1.5 %</b>	<b>94%</b>
Ulus S et al. (2016)	118	<b>1.7 %</b>	<b>72%</b>
Tarnoki DL et al. (2014)	22	<b>4.5 %</b>	<b>91%</b>

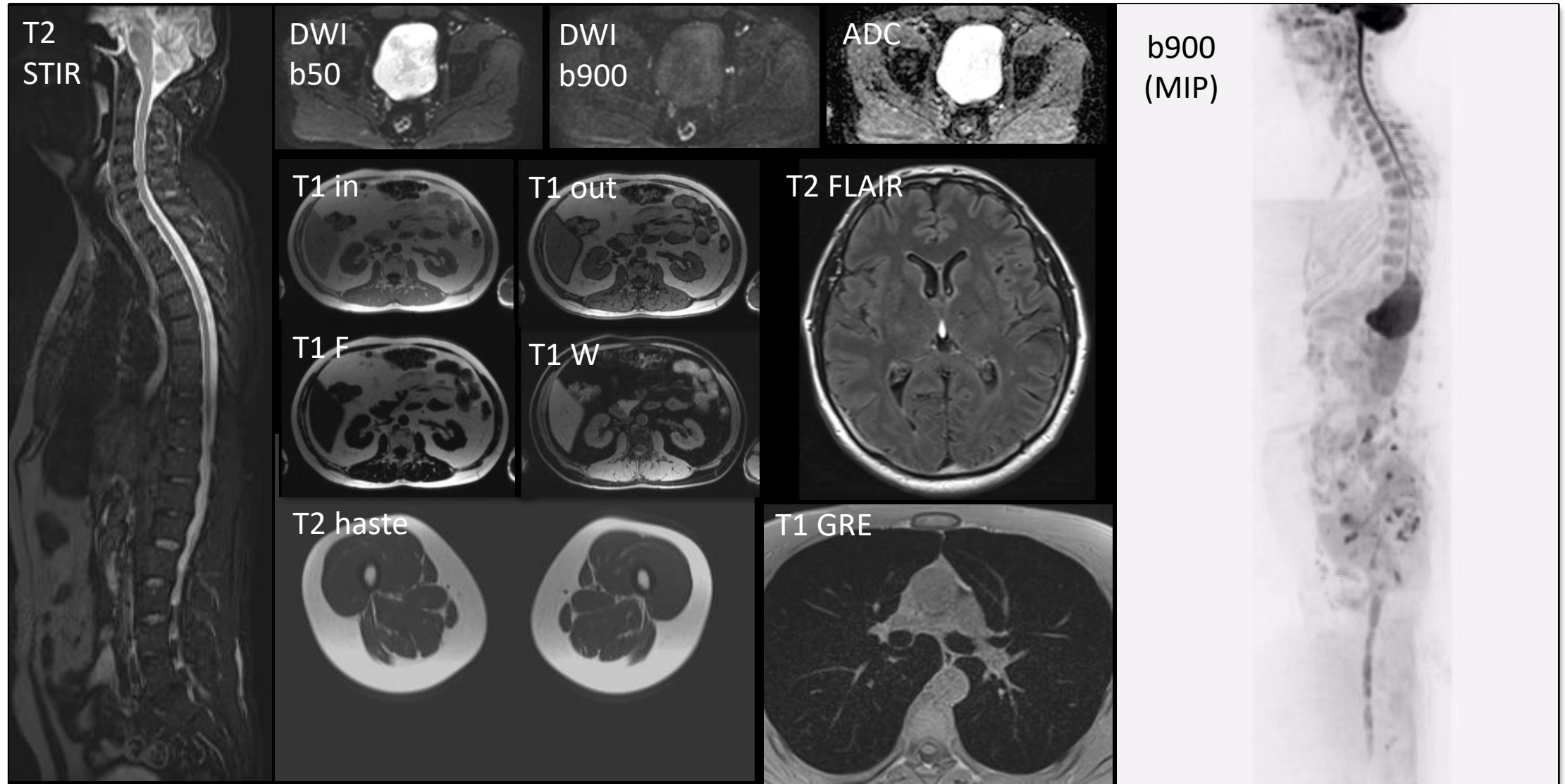
\* No histological confirmation

# Three aims of ONCO-RADS

Standardise

# 1. Acquisition

*WB-MRI protocol @1.5 & 3T (standard 50 mins / short 35 mins)*



## 2. Interpretation

*Abnormal findings assigned to one of the 7 body regions (bone, head, neck, chest, abdomen, pelvis, limbs)*

- **ONCO-RADS category (1 to 5)**
  - **ONCO-RADS 1**: normal
  - **ONCO-RADS 2**: benign finding highly likely
  - **ONCO-RADS 3**: benign finding likely
  - **ONCO-RADS 4**: malignant finding likely
  - **ONCO-RADS 5**: malignant finding highly likely

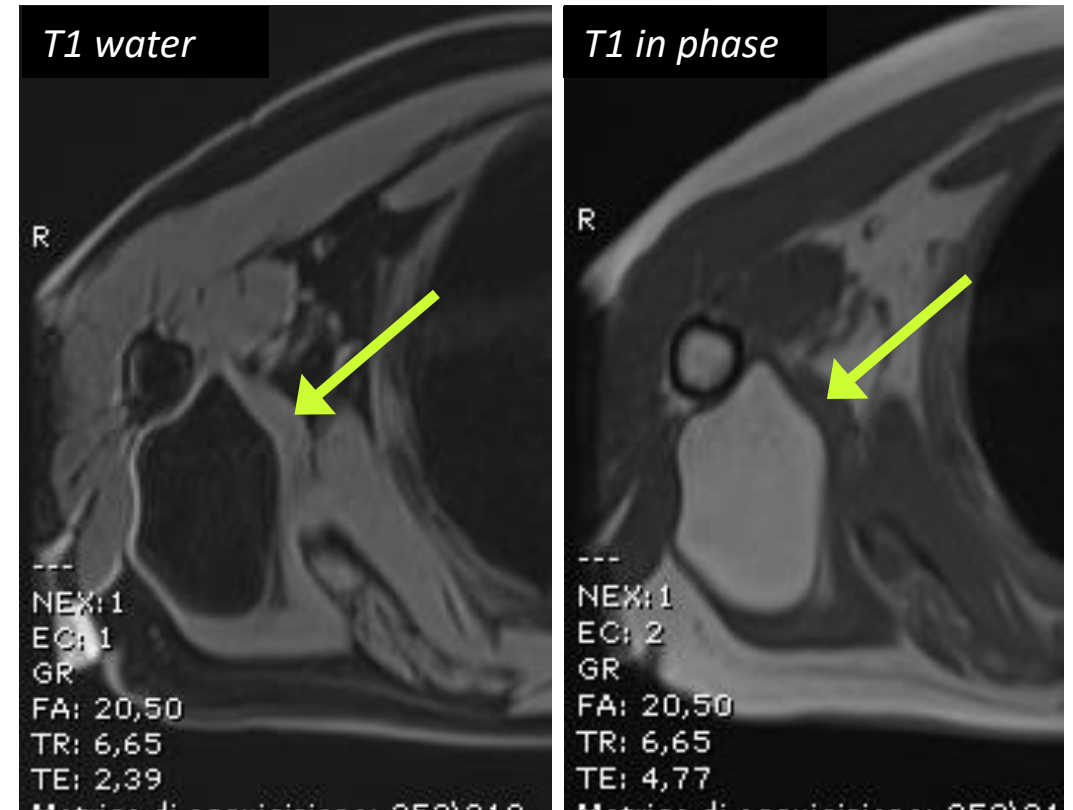
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- ONCO-RADS 3: benign finding likely
- ONCO-RADS 4: malignant finding likely
- ONCO-RADS 5: malignant finding highly likely

- 57yo, M (General population)
  - Asymptomatic
  - No history of cancer
  - PSA and FOBT are normal
  - Heavy smoker (>20 cigarettes per day x 20 years)



*ONCO-RADS 2 → No follow-up*



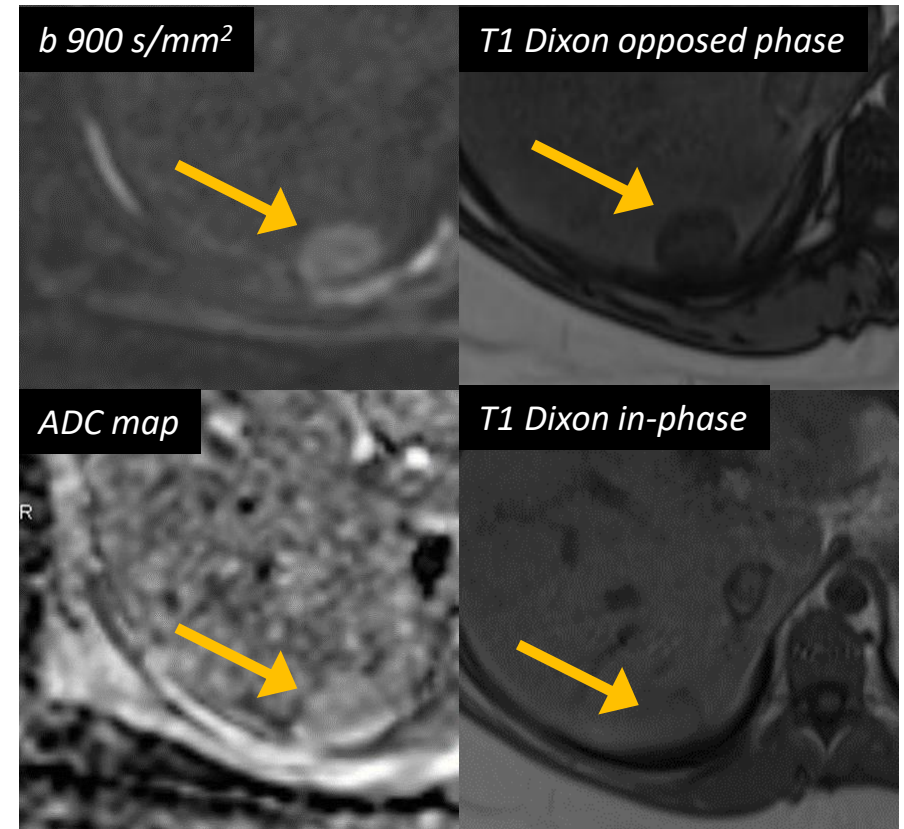
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- ONCO-RADS 5: malignant finding highly likely

- 29yo, F (LFS)
  - 2013 → Breast cancer
  - 2017 → Right inguinal dermatofibrosarcoma protuberans
  - 2018 → Recurrence (Surgery + RT)
  - 2020 → WB-MRI for cancer screening



*ONCO-RADS 3 → Biopsy (feasible)*

## 2. Interpretation

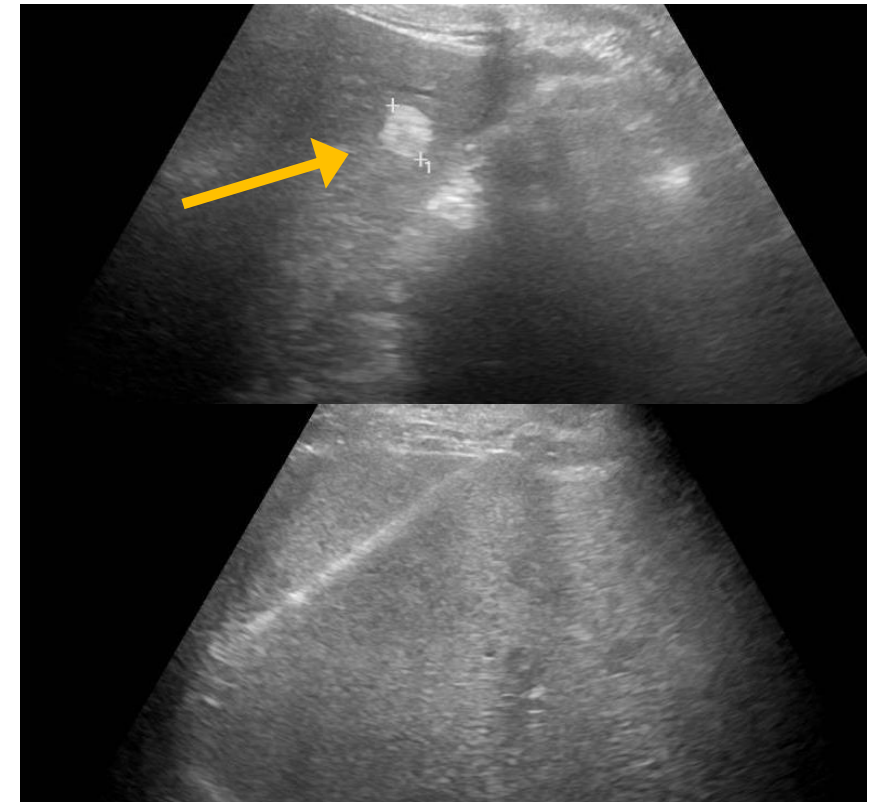
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- 29yo, F (LFS)

- 2013 → Breast cancer
- 2017 → Right inguinal dermatofibrosarcoma protuberans
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*Macrovesicular steatosis (intracellular)  
Signs of chronic inflammation & ductal  
hyperplasia/metaplasia  
STABLE AFTER 3 YEARS*

## 2. Interpretation

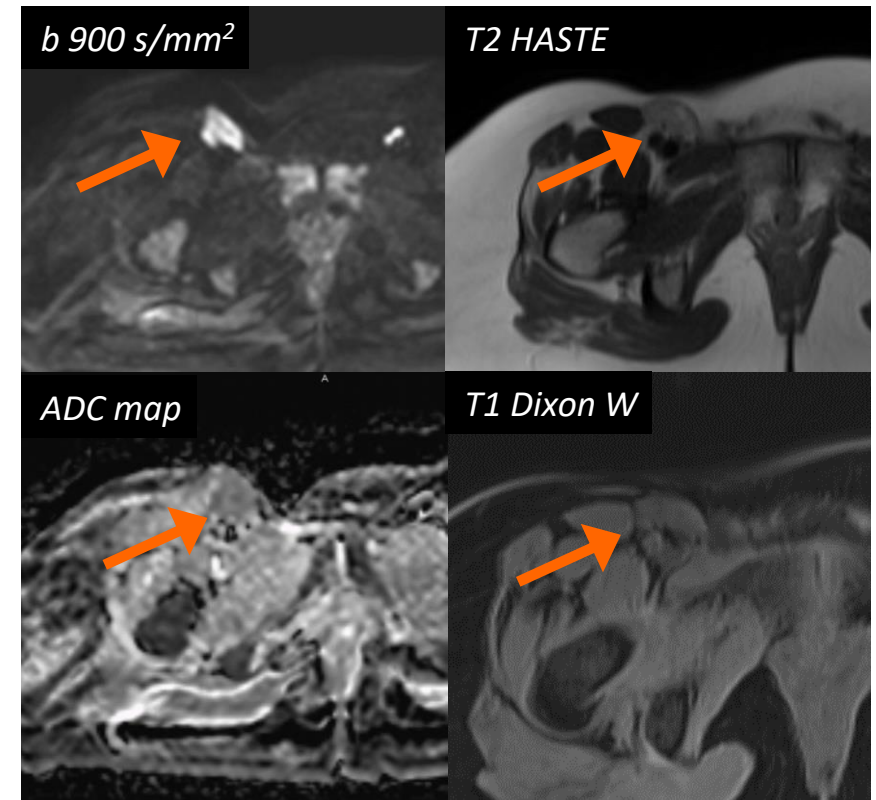
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- 29yo, F (LFS)

- 2013 → Breast cancer
- 2017 → Right inguinal dermatofibrosarcoma protuberans
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- 2020 → WB-MRI for cancer screening



**ONCO-RADS 4 → Biopsy / Surgery**

## 2. Interpretation

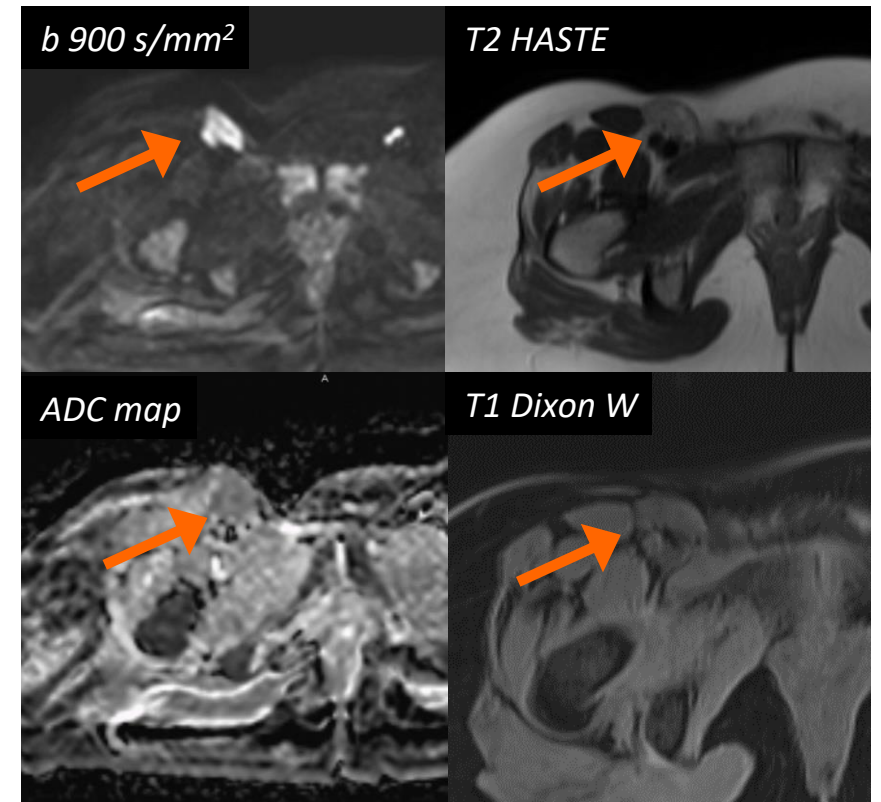
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- 29yo, F (LFS)

- 2013 → Breast cancer
- 2017 → Right inguinal dermatofibrosarcoma protuberans
- 2018 → Recurrence (Surgery + RT)
- 2020 → WB-MRI for cancer screening



*US-guided biopsy → Likely dermatofibrosarcoma protuberans  
After resection → Dermatofibrosarcoma protuberans*

## 2. Interpretation

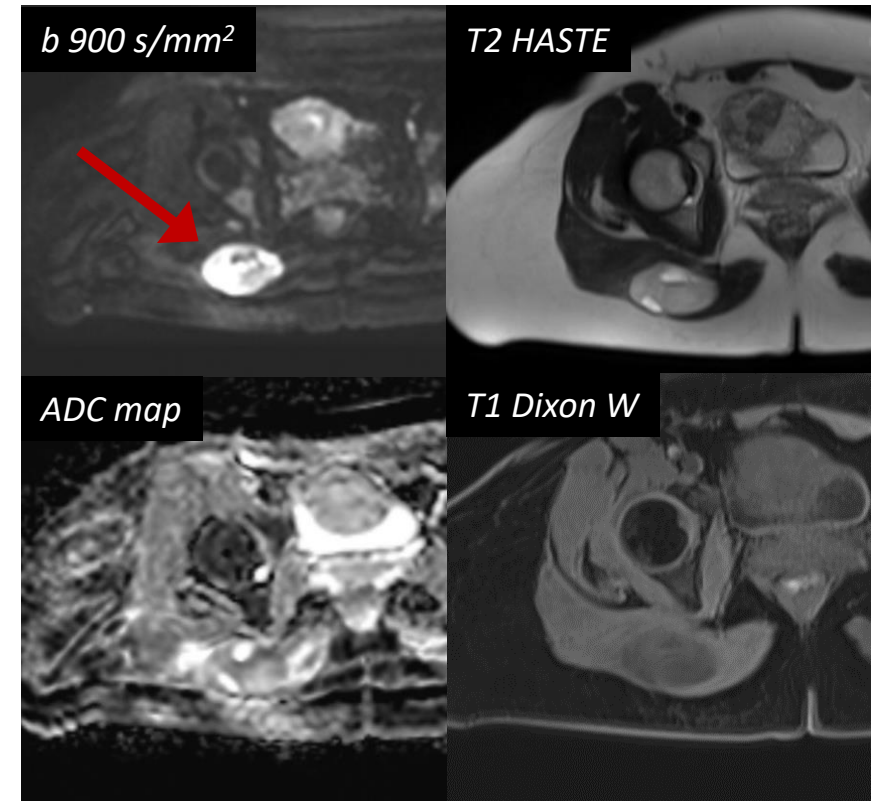
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- 29yo, F (LFS)

- 2013 → Breast cancer
- 2017 → Right inguinal dermatofibrosarcoma protuberans
- 2018 → Recurrence (Surgery + RT)
- 2020 → WB-MRI for cancer screening



**ONCO-RADS 5 → Surgery / Biopsy**

## 2. Interpretation

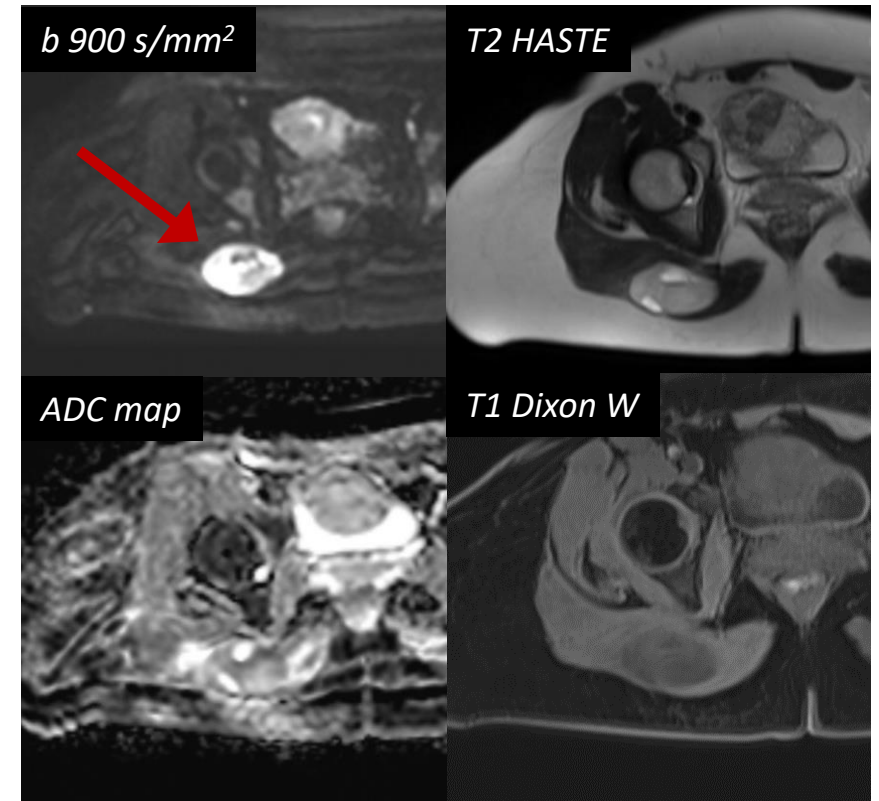
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- 29yo, F (LFS)

- 2013 → Breast cancer
- 2017 → Right inguinal dermatofibrosarcoma protuberans
- 2018 → Recurrence (Surgery + RT)
- 2020 → WB-MRI for cancer screening



*US-guided Biopsy → Likely dermatofibrosarcoma protuberans*

*After resection → High grade sarcoma*

**Table 4: Examples of the Most Frequently Observed Abnormal Findings in the Head, Neck, and Chest**

ONCO-RADS			
Category	Head	Neck	Chest
Category 1, normal finding	Normal	Normal	Normal
Category 2, benign finding highly likely	Diffuse white matter alterations, diffuse mucosal thickening of paranasal sinuses, pharynx and/or larynx, arachnoid cysts	Nonsuspicious thyroid nodule <1 cm (in individuals <35 y),* nonsuspicious thyroid nodule <1.5 cm (in individuals ≥35 y),* lipoma	Lung nodules <6 mm, <sup>†</sup> thymic hyperplasia, pericardial cysts, lipoma
Category 3, benign finding likely	Isolated white matter alterations, focal mucosal thickening of paranasal sinuses, pharynx and/or larynx	Nonsuspicious thyroid nodule ≥1 cm (in individuals <35 y),* nonsuspicious thyroid nodule ≥1.5 cm (in individuals ≥35 y)*	Lung nodules 6–8 mm, <sup>†</sup> pneumonia, pleural effusion
Category 4, malignant finding likely	Brain lesion(s) suspicious for cancer (primary or metastatic)	Thyroid nodule(s) (solid), salivary gland solid lesion	Lung nodules >8 mm, mediastinal mass
Category 5, malignant finding highly likely	Brain lesion(s) with aggressive features, very suspicious for cancer (primary or metastatic)	Thyroid nodule(s) with aggressive features, very suspicious for cancer	Lesions with aggressive features, very suspicious for cancer, to lung, mediastinum
Other findings, including anatomic variations	Hydrocephalus, hemorrhage, cavum septum pellucidum, cavum vergae, mega cisterna magna, Chiari malformations	Thyroglossal duct cyst	Pneumothorax, thoracic aortic aneurysm, azygos lobe, thoracic aorta variants (eg, right-sided aortic arch, double aortic arch)

**Table 5: Examples of the Most Frequently Observed Abnormal Findings in the Abdomen and Pelvis**

ONCO-RADS Category	Abdomen	Pelvis
Category 1, normal finding	Normal	Normal
Category 2, benign finding highly likely	Hemangioma (liver and spleen), cyst and hemorrhagic cyst <30 mm (kidney),* angiomyolipoma (kidney), adenoma (adrenal gland), steatosis (liver), lithiasis (gallbladder), lipoma	Benign prostatic hyperplasia (prostate), simple adnexal cyst ≤3 cm (postmenopausal),† simple adnexal cyst ≤5 cm (premenopausal), hemorrhagic adnexal cyst ≤5 cm (premenopausal),† ovarian fibroid,† uterine leiomyoma, para-ovarian cyst, luteal body
Category 3, benign finding likely	Solitary liver nodule ≥10 mm, solid likely focal nodular hyperplasia or adenoma, complex cyst (kidney), hemorrhagic cyst >30 mm (kidney),* pancreatic cyst ≤2.5 cm‡	Thickening of colorectal wall, simple adnexal cyst >3 cm (postmenopausal),† simple adnexal cyst >5 cm (premenopausal),† hemorrhagic adnexal cyst (postmenopausal),† hemorrhagic adnexal cyst >5 cm (premenopausal)†
Category 4, malignant finding likely	Lesion(s) suspicious for cancer in liver (solid nodules), kidney (solid lesion or cystic lesion with solid component),* pancreatic cyst with worrisome features (≥3 cm, thick wall, mural nodule, main pancreatic duct >7 mm)‡	Lesion(s) suspicious for cancer to uterus (eg, focal endometrial thickening), prostate (impeded diffusion and hypointensity on T2-weighted image in the peripheral zone), colon and rectum, simple adnexal cyst ≥10 cm, adnexal cyst with solid tissue, thick irregular septa, papillary projections, locules with different signal intensity†
Category 5, malignant finding highly likely	Lesion(s) with aggressive features in liver, kidney, pancreas, pancreatic cyst with high-risk features (solid component within the cyst, main pancreatic duct >10 mm, common bile duct dilatation)‡	Lesion(s) with aggressive features, very suspicious for cancer, to uterus, ovary, prostate, colon and rectum
Other findings, including anatomic variations	Abdominal aortic aneurysm, pancreas divisum, annular pancreas accessory spleen, inferior vena cava variants (persistent right posterior cardinal vein, persistent left supracardinal vein, retro-aortic left renal vein)	Fluid collection, uterine duplication anomalies (eg, uterus didelphys, bicornuate uterus septate uterus)



**Table 6: Examples of Most Frequently Observed Abnormal Findings in the Bones and Limbs**

ONCO-RADS Category	Bones	Limbs
Category 1, normal finding	Normal	Normal
Category 2, benign finding highly likely	Hemangioma, cyst, fat-poor bone marrow, bone island, enchondroma, healed fractures	Intramuscular hemangioma, lipoma
Category 3, benign finding likely	Bone lesion(s) with nonspecific features	Soft-tissue lesion(s) with unspecific features
Category 4, malignant finding likely	Bone lesion(s) suspicious for cancer (primary or metastatic)	Soft-tissue lesion(s) suspicious for cancer (primary or metastatic)
Category 5, malignant finding highly likely	Bone lesion(s) with aggressive features, very suspicious for cancer (primary or metastatic)	Lesion with aggressive features, very suspicious for cancer
Other findings, including anatomic variations	Fracture, transitional vertebrae (eg, lumbarization of S1, sacralization of L5)	Intramuscular hematoma

Note.—The threshold for assigning ONCO-RADS categories should be adapted to the individual's risk category (general population or higher risk including cancer predisposition syndromes). ONCO-RADS = Oncologically Relevant Findings Reporting and Data System.

# 3. Reporting

- Standardised reporting templates are available
  - Published in Supplemental Material (Appendix E3)
  - Download for free

## Appendix E3: Blank standardized report

### INDICATION:

*Cancer screening.*

High-risk individual (syndrome, etc)/asymptomatic individual of the general population

### TECHNIQUE:

Whole-body MRI (vertex to feet/mid thighs, including proximal upper limbs only).

Sequences: Whole-spine sagittal T1 W / T2 W STIR, axial TSE T2 W, axial GRE T1 Dixon, axial DW (b-values = 50 & 900 s/mm<sup>2</sup>).

Reconstructions: in-line (Water-only and Fat-only images, ADC maps), off-line (relative fat fraction, MIP, MPR).

### FINDINGS:

*MRI bone:*

No suspicious bone lesions.

Spinal canal dimensions within normal limits.

Sacral root cysts (ONCO-RADS category 2).

Vertebral body hemangioma/hemangiomas of Cx, Ty, Lz (ONCO-RADS category 2).

*MRI head:*

No suspicious brain lesions.

Ventricular system within normal limits.

Midline structures are not displaced.

Diffuse white matter alterations (ONCO-RADS category 2).

Mucosal thickening of the paranasal sinuses (ONCO-RADS category 2).

*MRI neck:*

Pharyngeal and laryngeal findings within limits.

No cervical enlarged lymph nodes.

Non-suspicious thyroid nodule < 1 cm/1.5 cm in the right/left lobe/s (ONCO-RADS category 2).

*MRI chest:*

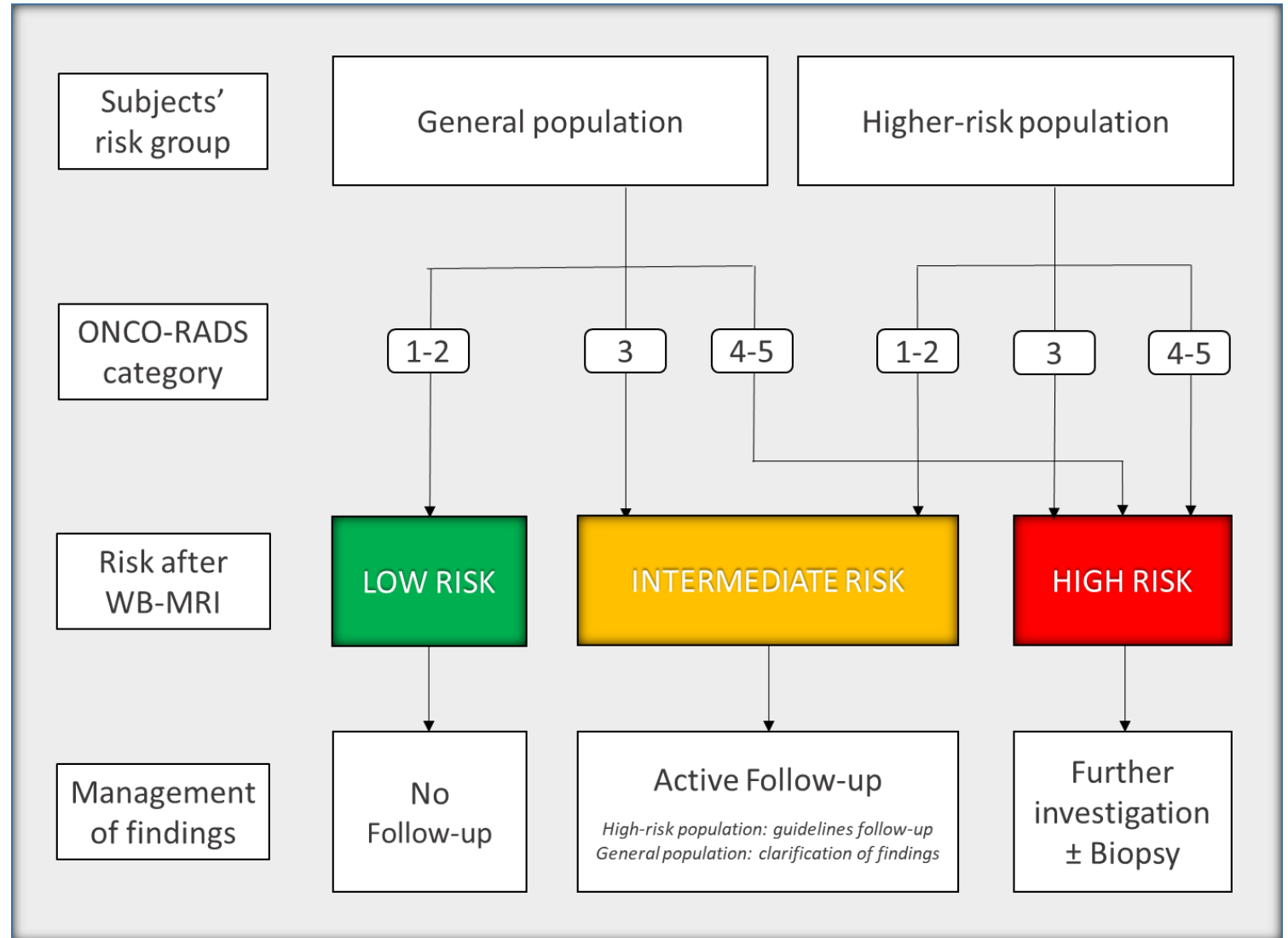
No suspicious lesions in either lung.

No enlarged mediastinal lymph nodes visible.

No enlarged supra-/subclavicular lymph nodes visible.

# In addition, management of findings «tailored» to the risk group

- High-risk populations
  - ONCO-RADS category 1-2 → Guidelines follow-up
  - ONCO-RADS category 3-4-5 → Further investigation ± Biopsy
- General population
  - ONCO-RADS category 1-2 → No follow-up
  - ONCO-RADS category 3 → Clarification of findings according to established guidelines for the management of incidental findings
  - ONCO-RADS category 4-5 → Further investigation ± Biopsy



Last, but not least → "Clinical" radiologist

- Before WB-MRI examination
  - WB-MRI → Addition to standard screening tests (and never in substitution)
    - Mammography, PAP smears, FOBT/colonoscopy
    - Avoid false reassurances
- After WB-MRI examination
  - Communication of the result
    - To ensure an **appropriate comprehension**
    - To **lower anxiety** related to the outcomes



Giacomo Agostini, 15 motorcycle world championships