

Update (Neuro-)Radiologie

Revision der MS-Diagnosekriterien & MS-Verlaufskontrolle: Herausforderungen & Möglichkeiten

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Facharzt für Radiologie (2008)
Schwerpunkt Neuroradiologie (2009)
Kurt-Decker-Preis DGNR (2007)
Lucien-Appel-Preis ESNR (2007)
Wissenschaftspreis DGNR (2009 & 2013)
FSL- und FreeSurfer-Kurse, HBM-/ISMRM-Lectures
OHBM Task Force "Presurgical fMRI"
DGNR Task Force 2024 Revision der McDonald-MS-Kriterien
Disclosures: Eisai, Novartis & Siemens Honoraria

MR-Kriterien für MS (bzw. entzündliche ZNS-Erkrankungen)

- Anzahl der Entmarkungsherde (*Läsionen*)
- Lokalisation der Entmarkungsherde
(periventrikulär, sub-/juxtakortikal = kortikomedullär / kortikal, infratentoriell, Optikus)
- Kontrastmittelaufnahme
- Örtliche (= *räumliche*) und zeitliche Dissemination

DIS:

Dissemination In Space

MAGNIMS 2016 vs. McDonald 2017: ≥ 2 von 5/4 DIS-Kriterien

1. ≥3 periventrikuläre Läsionen:
bei McDonald 2017 nur ≥ 1
"unless the patient is over the age of 50 in which case it is advised to seek a higher number of lesions"
2. ≥1 kortikale / juxtakortikale (= kortikomedulläre) Läsion
3. ≥1 infratentorielle Läsion
4. ≥1 spinale = (post-)myelitische Läsion
(2 für PPMS: konstituiert DIS!)
5. ≥1 Optikusentmarkung:
nicht Teil der 2017 rev. McDonald-Kriterien

MAGNIMS - MAGNetic Resonance Imaging in Multiple Sclerosis, European Collaborative Research Network
Ian McDonald (1933-2006) – neuseeländischer Neurologe, der die Kriterien federführend 2001 einführte

MAGNIMS 2016 vs. McDonald 2017

- **RBN als eigenständiges MRT-Kriterium**
(ca. 25% mit CIS kommen mit RBN)
- **≥ 3 vs. 1 periventrikuläre Entmarkungsherde**
(Sensitivität vs. Spezifität, pV+)
- **auch kortikale statt nur juxtakortikale Lokalisation**
- **sowohl symptomatische als auch „stille“ Läsionen werden für DIS & DIT berücksichtigt**

DIT:

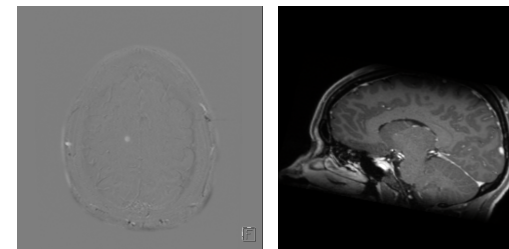
Dissemination In Time

u.a. zur Abgrenzung von monophasischen entzündlichen ZNS-Erkrankungen wie ADEM

DIT: MAGNIMS 2016 = McDonald 2017

1. **≥ 1 zu vorherigem MRT neue (NT2L - nicht größenprogrediente = ET2L !)**
Entmarkung (NT2L ± KM-Anreicherung; egal wann **und egal wo !**)
2. **gleichzeitige Detektion einer nicht anreichernden und einer KM aufnehmenden Entmarkung**

ABER: Typische Lokalisationen, das **WO** von (N)T2Ls?



RESEARCH ARTICLE | August 28, 2024 | <https://doi.org/10.1212/WNL.00000000000020975?> Check for updates

Association of Disease-Modifying Treatment With Outcome in Patients With Relapsing Multiple Sclerosis and Isolated MRI Activity

VIEW EDITORIAL

Gabriel Bsteh, PD, MD, PhD, MSc, Marie L. Aicher, MD, Janette F. Walde, PhD, Nik Krajnc, MD, PhD, Lukas Haider, MD, PhD, MBA, Gerhard Traxler, MD, Christiane Gradi, MD, ... [SHOW ALL](#) ... and Harald Hegen, MD, PhD, PD [AUTHORS INFO & AFFILIATIONS](#)

Discussion

In our real-world cohort of patients clinically stable under low-to-moderate-efficacy DMT, escalation of DMT based on isolated MRI activity decreased risk of further relapse when at least 2 new T2L had occurred.

Classification of Evidence

This study provides Class III evidence that clinically stable patients with MS on low-/moderate-efficacy DMT with ≥ 3 new T2L on MRI who escalate DMT have a reduced risk of relapse and Expanded Disability Status Scale progression.

ANNALS
of Clinical and Translational Neurology

RESEARCH ARTICLE

Improving criteria for dissemination in space in multiple sclerosis by including additional regions

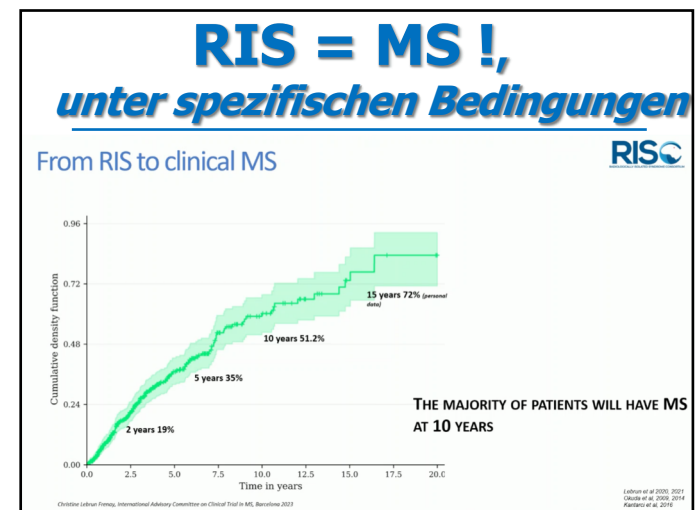
doi: 10.1002/acn3.52170 2024

Balken (E, F), Optikus (G), Temporallappen (H)
Optikus ↑ Sens. aber ↓ Spez.; 3/5 + 4/5 erhält Spez., +3 höchste Genauigkeit

McDonald 2024/5 Revision: Neuerungen

- ON# als 5. DIS-Topographie wie MAGNIMS 2016
- 4/5 DIS $\wedge$ CIS aber $\neg$ DIT: $\vdash$ MS[^]
- CSF kFLC äquivalent zu OKBs, kein GFAP
- CVS* und PRLs* als zusätzliche MRT-Marker
- RIS mit DIS+ qualifizieren für MS-Diagnose, wenn: DIT+ oder kFLC/OKB+[^] oder ≥ 6 CVS[^]

[^] entwirrt DIT; ON, Optikusneuritis; *demonstriert durch dediziertes Opticus-MR; kFLC, kappa free light chain
CVS, central vein sign; PRL, paramagnetic rim lesion; *durch phase-sensitive MR zu demonstrieren
Xavier Y. The 40th Congress of the European Committee for Treatment and Research in Multiple Sclerosis (ECTRIMS) – 18-20 September 2024

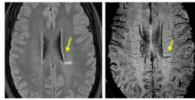


Was ist ein RIS ?

Das radiologisch isolierte Syndrom (RIS)

- wird durch den zufälligen Fund von wahrscheinlichen Entmarkungsherden des ZNS im MRT identifiziert,
- die morphologische und räumliche (!) Eigenschaften aufweisen, welche stark auf MS hindeuten, aber ohne klinische Symptomatik, die im Zusammenhang mit entzündlicher Demyelinisierung zu bringen wäre^{1,3}

The radiologically isolated syndrome (RIS) is identified by the incidental discovery of CNS **white matter T2-weighted hyperintense foci** on MRI that demonstrate morphological and spatial characteristics **highly typical of multiple sclerosis (MS)** but without clinical symptomatology related to inflammatory demyelination^{1,3}



1. Okuda DT, Mowry EM, Beheshtian A, et al. Incidental MRI anomalies suggestive of multiple sclerosis: The radiologically isolated syndrome. *Neurology*. 2009;72:800-805.
2. Lebrun C, Ikenis C, Delcroix M, et al. Association between clinical conversion to multiple sclerosis in radiologically isolated syndrome and magnetic resonance imaging, cerebrospinal fluid, and visual evoked potential: Follow-up of 70 patients. *Arch Neurol*. 2009;66:841-846.
3. Siva A, Srip S, Altintas A, Jacob A, Kegen EM, Kantarci GH. Multiple sclerosis risk in radiologically uncovered asymptomatic possible inflammatory-demyelinating disease. *Mult Scler*. 2009;15:918-927.

RIS-Kriterien: Mehr als inzidentelles DIS ?

Table 4 RIS criteria*

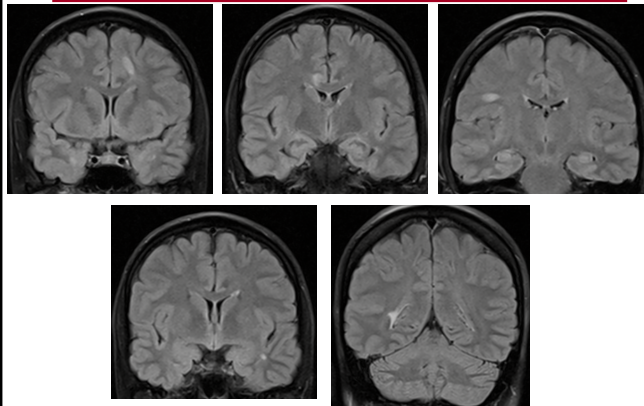
2009 RIS criteria	2023 RIS Criteria
A. The presence of incidentally identified CNS white matter anomalies meeting the following MRI criteria: (i) Ovoid, well-circumscribed, and homogeneous foci with or without involvement of the corpus callosum (ii) T₂-hypointensities measuring >3 mm and fulfilling Barkhof criteria (2 of 4 for dissemination in space) CNS anomalies not consistent with a vascular pattern B. No historical accounts of remitting clinical symptoms C. MRI anomalies do not account for clinically apparent impairments D. MRI anomalies are not due to the direct physiological effects of substances E. Exclusion of MRI phenotypes suggestive of leukoencephalitis or extensive white matter pathology lacking involvement of the corpus callosum F. MRI anomalies not better accounted for by another disease process	I. Radiological criteria A. MRI with incidental CNS white matter anomalies demonstrating radiological characteristics highly suggestive of demyelinating disease and meeting the following criteria: (i) Ovoid, well-circumscribed, and homogeneous foci >3 mm² with or without the involvement of the corpus callosum (ii) Involvement of periventricular, juxtacortical, infratentorial and spinal cord regions (iii) Anomalies inconsistent with a microvascular or non-specific white matter disease pattern With: B. Index MRI fulfilling 3 or 4 of 4 dissemination in space criteria according to the 2005 multiple sclerosis diagnostic imaging criteria. Or C. Index MRI fulfilling at least one of four dissemination in space requirements^a, additionally fulfilling two of the following: (i) Presence of abnormal CSF restricted OCBs (ii) Presence of at least one spinal cord lesion consistent with inflammatory demyelination (iii) Evidence of dissemination in time on any follow-up MRI defined by the presence of one or more new T₂-weighted hyperintensities or gadolinium enhancement typical for MS^b II. Exclusion criteria A. No historical account of relapsing remitting or progressive clinical symptoms consistent with neurological dysfunction B. MRI anomalies or neurological examination findings do not account for clinically apparent impairment(s) to the individual C. Another disease process has not been identified to better account for the CNS MRI anomalies.

4/5 DIS + ODER
1/5 DIS + UND 2/3 der folgenden:

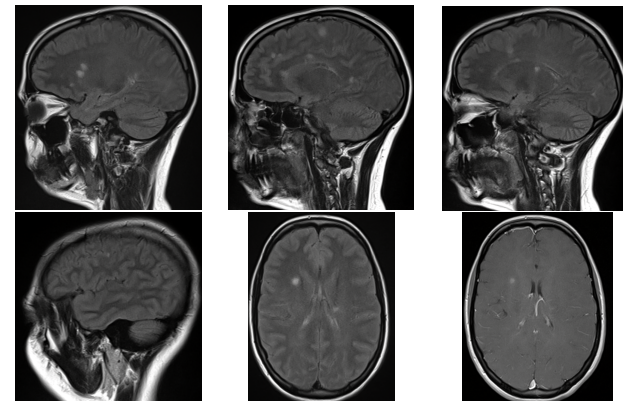
- a) CSF +
- b) ≥ 1 (post-)myelitischer Herd
- c) DIT +

Lebrun-Fréhny et al., Brain 2023

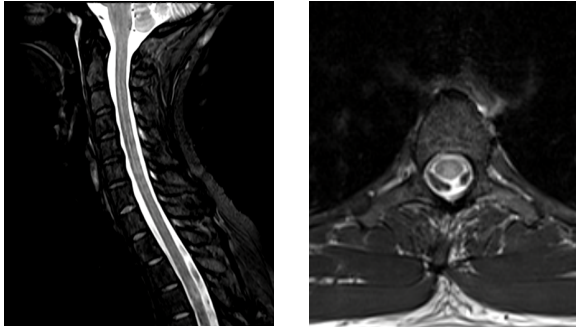
RIS in der Praxis: MB, ♀, 20 a 08/2012



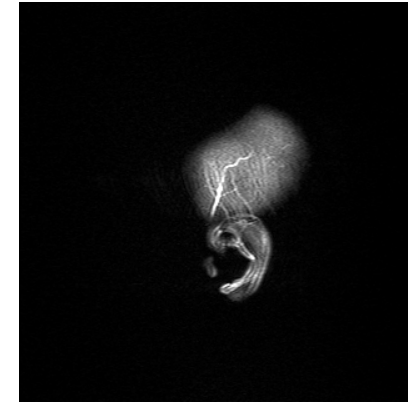
RIS in der Praxis: MB, ♀, 21 a 06/2013



RIS in der Praxis: MB, ♀, 26 a 08/2018



RIS in der Praxis: MB, ♀, 29 a 10/2020



McDonald 2024/5 Revision: Guidelines

ECTRIMS 2025
Barcelona, Spain

41st ECTRIMS Congress
30th RIMS Conference

Pre-Day | 23 September
Annual Congress | 24-26 September
Patient Community Day | 26 September

ECTRIMS RIMS

Abstract Number: [2571]

Abstract Title: Expert panel consensus guidelines of the German Society of Neuroradiology on the use of magnetic resonance imaging in the diagnosis and monitoring of multiple sclerosis

Abstract Category: 3. IMAGING & NON-IMAGING BIOMARKERS - 3.1 MRI

Preferred Presentation Type: Oral or poster presentation

Mike P. Wattjes^{*1}, Carsten Lukas², Sonke Langner³, Hagen H. Kitzler⁴, Andreas Bartsch⁵, Michael Scheel¹, Wiestler Benedikt⁶

McDonald 2024/5 Revision: Guidelines

ECTRIMS 2025
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ECTRIMS RIMS

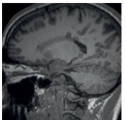
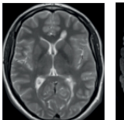
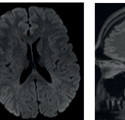
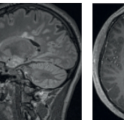
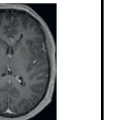
Conclusions:

We suggest continuous use of the acquisition protocol established by the 2021 MAGNIMS-NAIMS-CMSC consensus recommendations. *For the patients with conclusive MS*, this protocol is diagnostically sufficient.

For patients with inconclusive MRI findings to diagnose MS, we recommend to incorporate:
a) optic nerve MRI to detect optic nerve lesions (when VEP / OCT are not available or indecisive) and
b) phase-sensitive SWI sequences to detect PRLs and / or CVS lesions.

For MS monitoring, demonstration of PRLs and slowly expanding lesions (SELs) may become prognostically relevant.

MS-cMRT nach MAGNIMS(-CMSC-NAIMS) 2021

3D T1-weighted (optional)	2D turbo spin echo T2-weighted*	Diffusion-weighted imaging (optional)†	3D T2-weighted FLAIR‡	2D or 3D contrast-enhanced T1-weighted (optional)
				

Contrast injection in selected cases§

Minimum delay 5-10 min

Figure 1: Recommended brain MRI protocol
 In selected cases, contrast agent can be injected just before the 3D T2-weighted FLAIR; the delay to the start of the 2D or 3D contrast-enhanced T1-weighted imaging should be a minimum of 5-10 min. Spatial resolution parameters for 3D sequences are $\leq 1 \text{ mm} \times 1 \text{ mm} \times 1 \text{ mm}$ (ie, multiplanar reconstruction 3 mm). Spatial resolution parameters for 2D sequences are $\leq 1 \text{ mm} \times 1 \text{ mm} \times \leq 3 \text{ mm}$ (table 1). 3D=three dimensional, 2D=two dimensional, FLAIR=fluid-attenuated inversion recovery, *Either single or dual echo, Can be skipped if there is good quality 3D FLAIR in the monitoring protocol, †For differential diagnosis, ‡Transverse 2D FLAIR could be considered as an alternative, if 3D-FLAIR not available or not of good quality, §0.1 mmol/kg bodyweight of macrocyclic agents.

The Lancet Neurology DOI: (10.1016/S1474-4422(21)00095-8)

MS-cMRT für McDonald 2024/5

Empfohlen

Kernprotokoll

Optional

3D T1, SWI**

3D T2-FLAIR*, 2D T2-TSE*, T1-Gad*

2D T2-FS/STIR for ON

0.1 mmol/kg BW Gadolinium (makrozyklisches Gadolinium)

minimales Delay 5 Minuten

Magnetische Feldstärke: $\geq 1.5 \text{ T}$, 3T empfohlen

Örtliche Auflösung:
 2D: 3 mm Schichtdicke (kein gap), in-plane $\leq 1 \times 1 \text{ mm}^2$
 3D: $\cong$ isotrope Voxelgröße $\leq 1 \times 1 \times 1 \text{ mm}^3$

* 3D oder 2D Bildakquisition, 3D für FLAIR empfohlen
 * Proton density PD optional, ohne PD bei z.B. radialem k-space sampling
 † inklusive Phasenbildrekonstruktion

Dr-dimensional, STIR=short tau inversion recovery, FS=fat saturated, FLAIR=fluid attenuated inversion recovery, Gad=Gadolinium, BW=body weight, T=Tesla

Wattjes MP et al. (in preparation)

MS-sMRT für McDonald 2024/5

Sagittal STIR*, T2*, PD*, T1 Gad*, axial T2

0.1 mmol/kg BW Gadolinium (makrozyklisches Gadolinium), min. Delay 5min

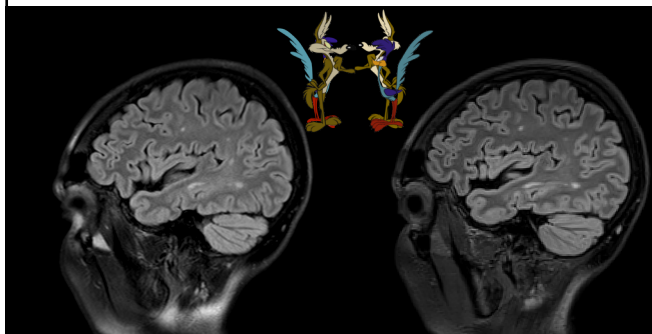
Magnetische Feldstärke: $\geq 1.5 \text{ T}$

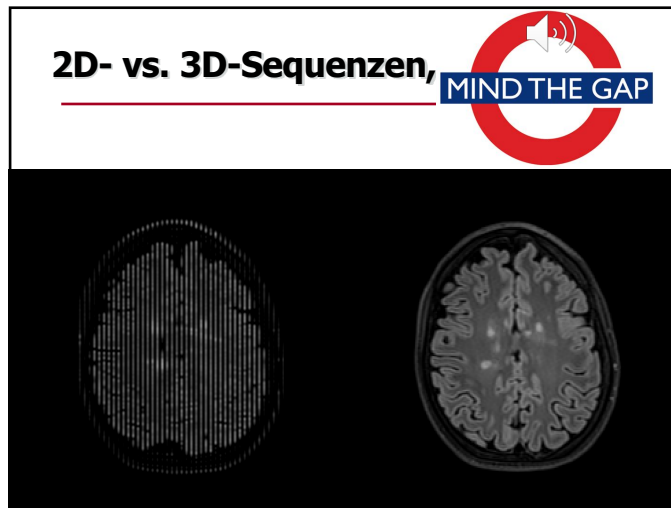
Örtliche Auflösung:
 2D: 3 mm Schichtdicke (kein gap), in-plane $\leq 1 \times 1 \text{ mm}$
 3D: $\cong$ isotrope Voxelgröße $\leq 1 \times 1 \times 1 \text{ mm}$

* combination of at least two of these sequences
 STIR=short tau inversion recovery, T2=T2-weighted, PD=Proton density, Gad=Gadolinium, BW=body weight, T=Tesla

Wattjes MP et al. (in preparation)

2D- vs. 3D-Sequenzen: Vor- und Nachteile





MAGNIMS 2021: Standardisierte Befundung

Category	Parameters/findings to report
MRI technique	A brief, concise description of the MRI technique should include: - anatomical area covered (brain, spinal cord, optic nerve) - magnetic field strength - slice thickness - type and dose of GBCA used - type of sequences performed - date and technique of previous scan used for comparison These data are required for proper comparative analysis of examinations that are performed at different time points and at different imaging centres
Findings	This section should start with a comprehensive, systematic description of all the imaging findings related to the specific clinical situation, using standardized terminology. Examples of such findings include: - Lesions: number of T2 lesions* and of Gd-enhancing lesions, topography, size, and shape (with reference to MS characteristics) (on diagnostic scan) - qualitative assessment of T2 and T1 lesion load - semiquantitative visual assessment of brain atrophy - positive and negative imaging features that could be considered as evidence for or against the diagnosis of MS - on follow-up scans, the number of unique active lesions defined as Gd enhancing lesions plus unenhanced new and substantially enlarged T2-hyperintense lesions should be reported (in addition to a brief summary of the points above) - any incidental or unexpected findings, which should be clearly described and interpreted as either clinically relevant or not

GBCA=gadolinium-based contrast agent

* Suggested system for reporting total T2 lesion number: Brain: If <20 lesions, provide exact number; otherwise, report an estimate of "between 20 and 50 lesions," "between 50 and 100 lesions," "more than 100 lesions," or "uncountable (confluent) lesions." Spinal cord: If <10 lesions, provide exact number; otherwise, report "more than 10 lesions" or "diffuse pattern."

The Lancet Neurology DOI: (10.1016/S1474-4422(21)00095-8)

Standardisierte MRT-Befundung

- **Erstuntersuchung oder Kontrollbildgebung?**
- **Erstuntersuchung:** cMRT, HWS/BWS-MRT, ggf. Optikus; Kontrolle: cMRT +/- spinal, nach MAGNIMS 2021 Empf.
- **Initiale Diagnostik:** Anzahl + Lokalisation der Läsionen infra-/supratentoriell / (post-) myelitisch, Schrankenstörungen, DIS / DIT, Läsionslast (Konfluenz, diffuser Befall), **CVS / PRLs**, kortikale Läsionen: **CLs**, **"black-holes"**, Atrophie, Bezug zur Klinik (symptomatisch vs. stumm), DD, Nebenbefunde
- **Follow-up:** Letzte VA wann? In domo / alio loco? Neue (**NT2L**) oder größenprogrediente (**ET2L / SELs**) infra-/supra-/ (post-)myelische Herde?, **PRLs**, floride Entzündungsaktivität (Schrankenstörungen)?, Läsionslast, Atrophieprogression, Bezug zur Klinik (Schübe / Progression vs. stumm), kernspintomographisch E(I)DA vs. NE(I)DA(-IV), **Komplikationen (PML, IRIS, JCV-GNP etc.)**

Wie soll MS-MRT erfolgen ?

■ Bindende KV-Vorgaben

■ 2021 MAGNIMS-CMCS-NAIMS Empfehlungen

(Lancet Neurol [https://doi.org/10.1016/S1474-4422\(21\)00095-8](https://doi.org/10.1016/S1474-4422(21)00095-8))

CMSC – Consortium of Multiple Sclerosis Centres

NAIMS – North American Imaging in Multiple Sclerosis Cooperative

KV-Vorgaben 2020

Richtlinie



des Gemeinsamen Bundesausschusses
über Kriterien zur Qualitätsbeurteilung in der
Kernspintomographie nach § 135b Absatz 2
SGB V

(Qualitätsbeurteilungs-Richtlinie
Kernspintomographie/QBK-RL)

in der Fassung vom 17. Oktober 2019
veröffentlicht im Bundesanzeiger (BAnz AT 30.01.2020 B3)
in Kraft getreten am 1. Januar 2020

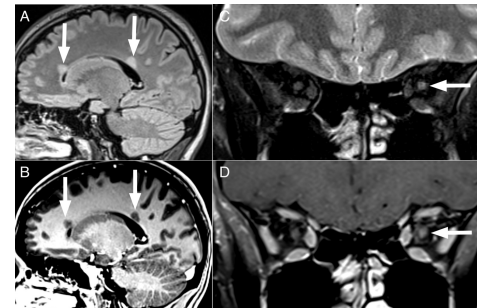
MS-MRT nach QBK-RL 2020

- nur Neurokranium geregelt, *nicht Myelon oder Optikus*
- keine Empfehlung zur *Feldstärke*
- i.v. KM: *obligat* zur *Diagnosestellung* bei Erstmanifestation; *fakultativ* zur *Verlaufskontrolle* (mindestens 5 Minuten vor T1 Gd), *Darstellung in zwei Ebenen*
- 2D: 1x1x**5mm**, 3D: **1.5mm** isotrop, **FoV 250mm**
- axial T2-FLAIR und T1 und **sagittal T2** oder axial T2.PD und T1 und **sagittal T2**, *keine SWI*
- Referenzstrukturen: GM/WM, *fokale Läsionen >3mm*, *T1-hypointense Läsionen („black holes“)*, *KM-anreichernde bzw. neue Läsionen im Verlauf, DIS / DIT*

MRT Qualitätskontrollen der KV

- nur Befund zum kontrollierten Zeitpunkt wird bewertet
- keine bindende Orientierung an MAGNIMS-Empfehlungen
- Voruntersuchungen bleiben unberücksichtigt, werden nicht auch angefordert
- Keine Evaluation von CVS, PRL, NT2L, ET2L, SEL, Atrophie und deren Progression etc.

ON: MRT-Bildgebung für RBN

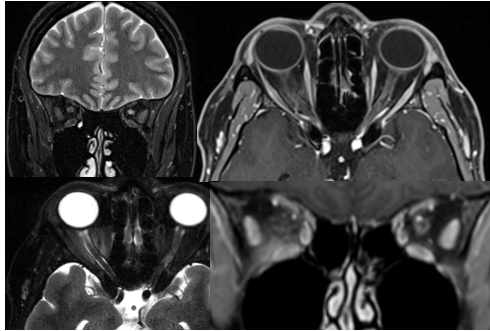


22 a, ♀, akute ON/RBN li, 2 periventrikuläre Läsionen,

MAGNIMS 2016 ⊖ & McDonald 2017 ⊖, 2024/5 ⊕

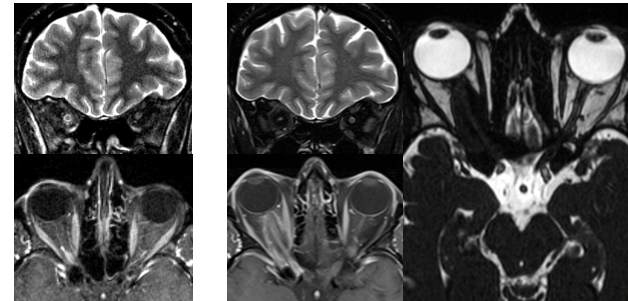
Case courtesy of MP Wattjes

Isolierte ON



41 a, ♀, sieht seit 2 Wo auf dem li Auge „anders“, kein Michglassesehen, keine Farbentsättigung, nur kurz wenig retrobulbärer Schmerz;
Außenrand- Δ periventriculäre Herde? zirkuläres Außenrand- Δ Ringenhancement vom Opticus?

DD zur ON / RBN

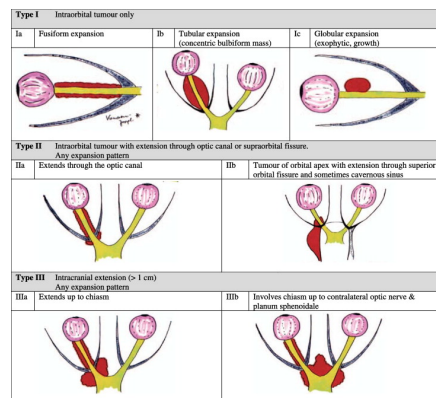


05/2006

07/2015

38a, ♀, 05/2006 RBN-Dx + 1.MRT, f/u: 07/2006 + 01/2007 + 10/2010 + 06/2013 + 07/2015 (48a, re blind)

Eine DD der ON: Optikusscheidenmeningeome (OSM)



Schick et al. J Neurosurg. 2004 Dec;101(6):951-9

ON-MRT: Wann zur MS-Diagnose?

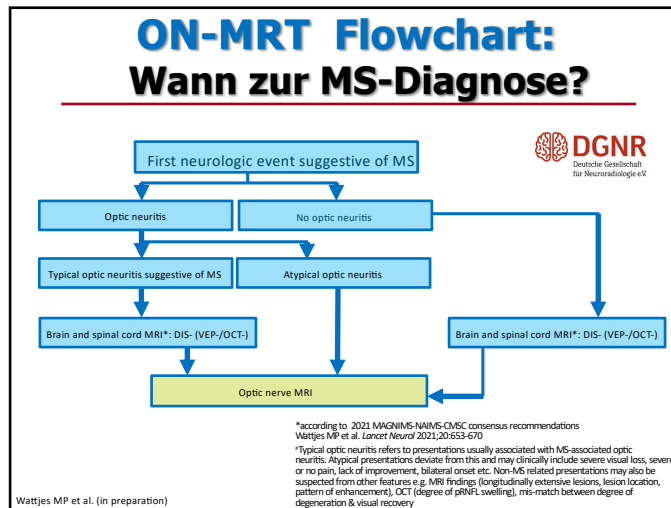
■ **Empfohlen:** a) CIS $\pm$ ON, DIS* von Hirn- + Myelon-MRT nicht erfüllt und VEP, OCT o./u. ERG nicht verfügbar / vorliegend oder inkonklusiv

b) Pat. $\pm$ ON bei schwierigen DDs (z.B. NMOSD, MOGAD, aber auch Optikusscheidenmeningeom)

■ **Optional:** CIS $\pm$ ON, DIS* von Hirn- + Myelon-MRT bereits erfüllt (FP-Risiko, Konsequenz?)

■ **Nicht empfohlen:** CIS $\pm$ ON, zuvor kein DIS* nach Optikus-, Hirn- + Myelon-MRT, bei f/u MRT, um DIS/DIT zu demonstrieren/verwerfen, klin. Monitoring $\pm$ VEP/OCT/ERG auf ON vorausgesetzt

ON, Optikusneuritis
*nach MRT, das den MAGNIMS-NAIMS-CMSC-Vorgaben folgt



ON-MRT: Wann zum MS-Monitoring?

- **Empfohlen:** unklare Klinik, potentiell auf ON zurückzuführen
- **Nicht empfohlen:** Standard-MS-Monitoring ± DMT

ON-MRT: Wie?

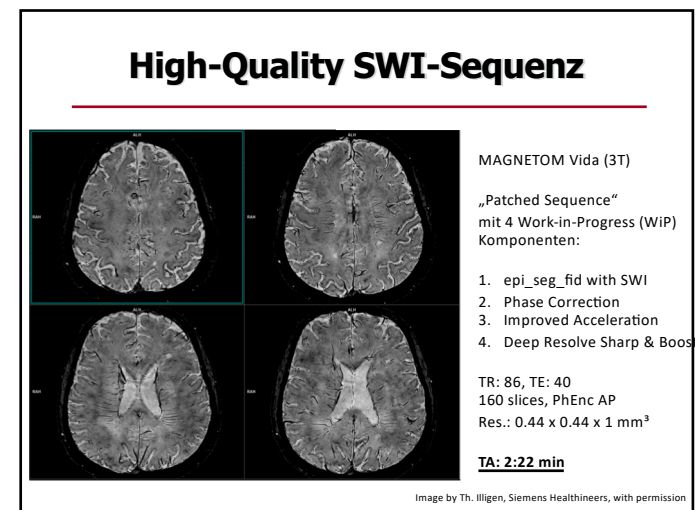
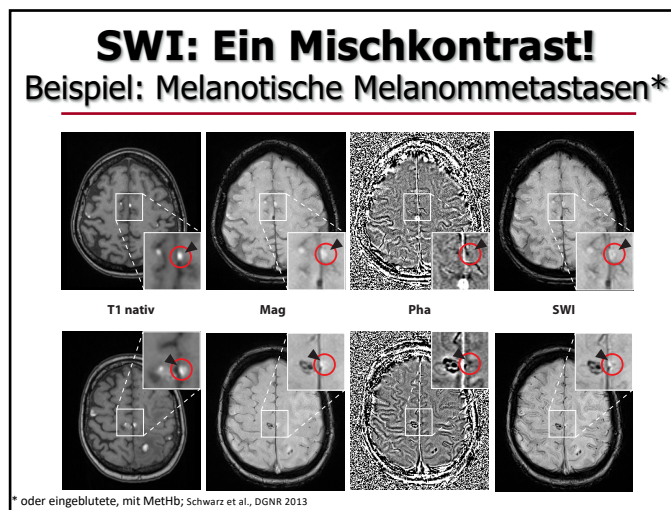
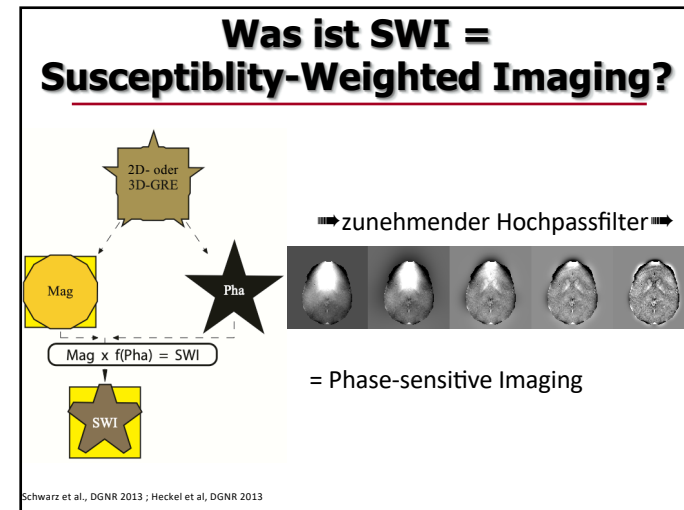
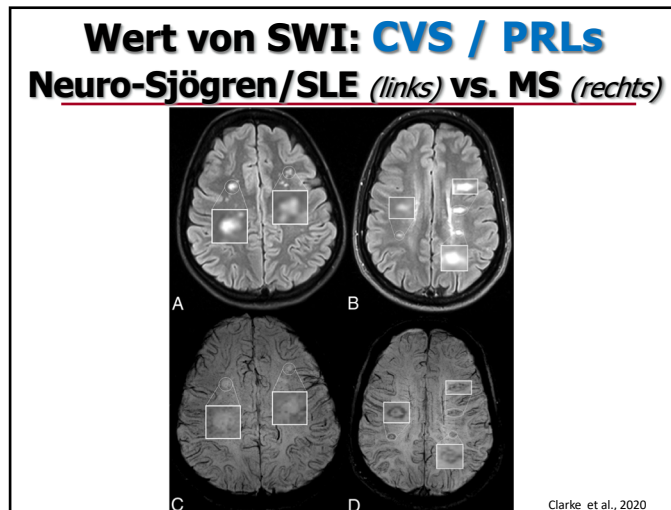
- **Feldstärke:** ≥ 1.5 Tesla
- **Auflösung:** in plane ≤ 1x1mm (zu unambitioniert?°), 2-3mm Schichtdicke, kein Gap
- **Abdeckung:** ON und Chiasma opticum
- **Angulation:** koronar (⊥ ON), axial (⊥ kor.)
- **Wichtungen:** T2- (Schlüsselsequenz!) / T1- (Turbo/Fast)SE FatSat*, T1 nativ/postKM; optional: 3D DIR[#]

ON, Optikusneuritis; RBN, Retrobulbärneuritis; ° Optikusquerschnitt nur ca. 9mm²;
 * alternativ 2D STIR oder T2-DIXON (Vorteil: fettunterdrücktes Bild dabei, siehe OSM-Fall;
[#] nur für einen Gerätehersteller bei 3T validiert

CVS / PRL-MRT: Wie?

- **Feldstärke:** ≥ 1.5 Tesla, 3 Tesla sinnvoll
- **Sequenz:** phasensensitive GRE SWI (Schlüsselsequenz!, 2/3D)
- **Abdeckung:** supra- & infratentorielles Hirn
- **Angulation:** axial
- **Auflösung:** TE ≥ 20 ms oder Multi-Echo, in plane ≤ 1x1mm (0.8mm?), ≤3mm Schichtdicke/reko, kein Gap

SWI, susceptibility-weighted imaging



ABER: SWI (WAVE-CAPI) bei 1.5 Tesla kann sehr schlecht werden

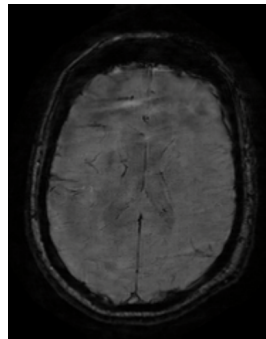


Image by PD Dr. A.J. Bartsch, Radiologie Bamberg

UND: SWI vom Myelon auch bei 3 Tesla

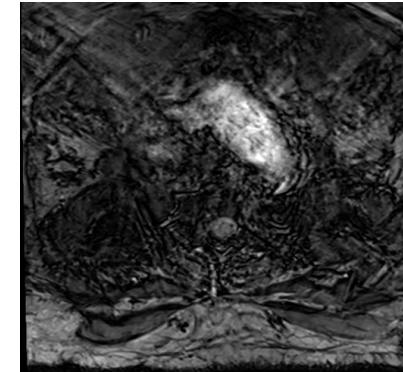
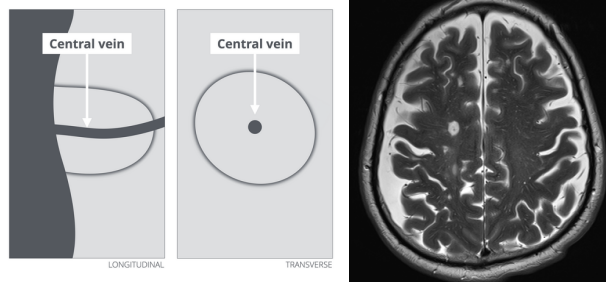


Image by PD Dr. A.J. Bartsch, Radiologie Bamberg

Was sind „central vein signs“ (CVS)?

Central vein sign



courtesy of Frank Gaillard, Radiopaedia.org, rID: 197467

Definition des CVS

Box 2 | Radiological definition of a central vein

A central vein exhibits the following properties on

T2*-weighted images: **Besser: Phase-sensitive Imaging!**

- Appears as a thin hypointense line or small hypointense dot
- Can be visualized in at least two perpendicular MRI planes, and appears as a thin line in at least one plane
- Has a small apparent diameter (<2 mm)
- Runs partially or entirely through the lesion
- Is positioned centrally in the lesion (that is, located approximately equidistant from the lesion's edges and passing through the edge at no more than two places), regardless of the lesion's shape

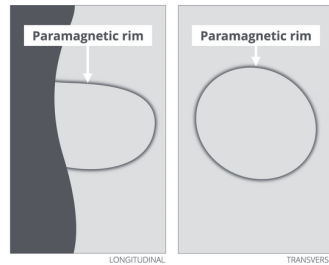
Exclusion criteria for lesions:

- Lesion is <3 mm in diameter in any plane
- Lesion merges with another lesion (confluent lesions)
- Lesion has multiple distinct veins
- Lesion is poorly visible (owing to motion or other MRI-related artefacts)

NAIMS-CMSC
Sati et al., Nat Rev Neurol 2016
Mazzei et al., Ann Neurol 2018

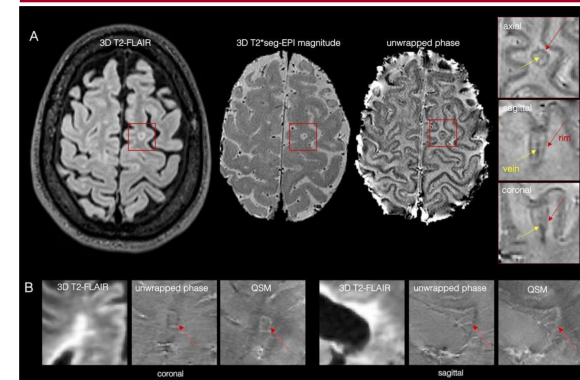
Was sind „paramagnetic rim lesions“ (PRL)?

Paramagnetic rim lesions



courtesy of Frank Gaillard, Radiopaedia.org, rID: 197467

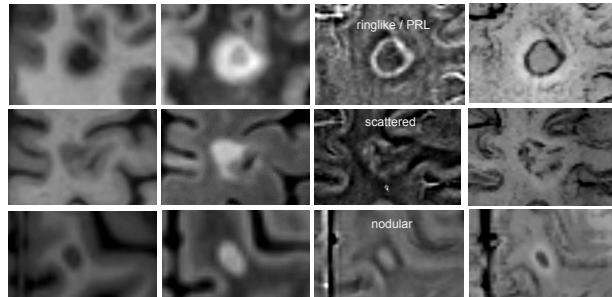
Was sind „paramagnetic rim lesions“ (PRL)?



la Rosa et al., NeuroImage: Clinical. 2022

Was sind „paramagnetic rim lesions“ (PRL)?

Paramagnetische Ringläsionen (*Paramagnetic Rim Lesions*; PRLs) Gruppe chronisch aktiver MS-Läsionen mit Eisen-beladener Mikroglia/Makrophagen



Vollständiges Bild der MRT-Phänomene bisher unbekannt

courtesy of Hagen Kitzler, Dresden

Was sind „paramagnetic rim lesions“ (PRL)?

Läsionsdefinition

Phase und SWI (keine Magnitude-Beurteilung zur Bestimmung notwendig)

Pitfall nur Pha+! (unklar)

Pitfall nur SWI+! (starke Demyelinisierung/CSF)

Mind. 2 Schichten abgrenzbar bei Schichtdicke 3 mm (nötig? ≥ 3 mm?)

Welche Läsionen werden gewertet?

Paramagnetische Ring-Läsion (PRL)

Paramagnetische Streu-Läsion (PSL)

Paramagnetische Nodus-Läsion (PNL)

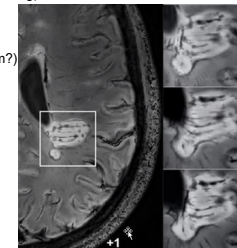
Bei PRL – Welche Ringkonfiguration ausreichend?

Ring vollständig geschlossen o. max. 2 Unterbrechungen

Umgang mit Konglomeraten (PRL ≥ 1 , ok)

Umgang mit dynamischen Veränderungen (Zahl, Größe, Kategorie?)

PRL nur als chronische Läsionen definiert, neue T2I mit SWI+? (Ontaneda et al.)



courtesy of Hagen Kitzler, Dresden

CVS und PRL bei MS

Central vein sign and Paramagnetic rim lesions

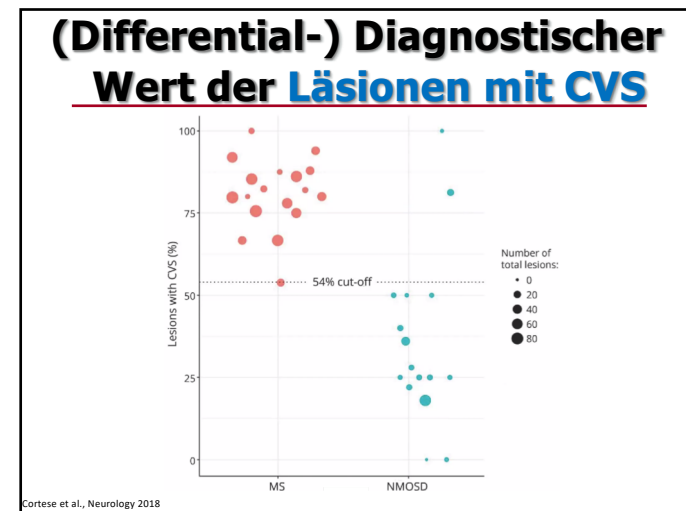
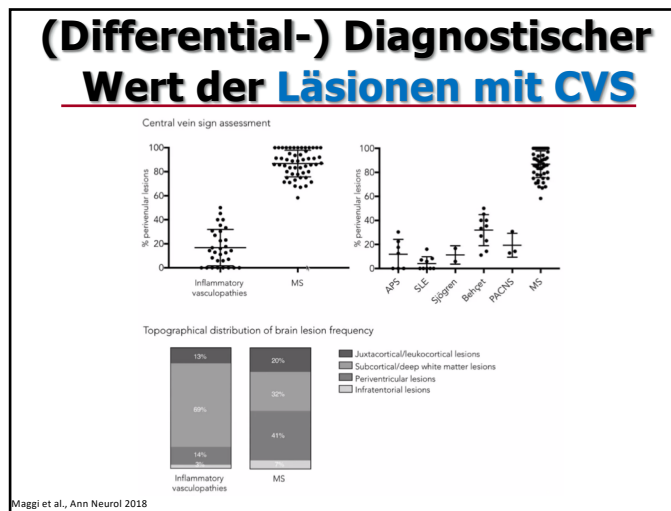
courtesy of Frank Gaillard, Radiopaedia.org, rID: 197467; Case courtesy of Alan Coulthard, Radiopaedia.org, rID: 80826; Meaton et al., Mult Scler. 2022

Differentialdiagnose von CVS und PRLs als solchen

CVS & PRLs sind u.a. zu unterscheiden von:

- **CVS:** Gliosen um transmedulläre Venen von DVAs (venösen Angiomen)
- **Noduläre PRLs:** perivaskuläre Räume (PVS; Virchow-Robin) in T1-gew. SWI (Magnitudenbild), granulomatöse Herde?, CLIPPERS?, Ependymome ...

DVA, developmental venous anomaly



(Differential-) Diagnostischer Wert der Läsionen mit CVS

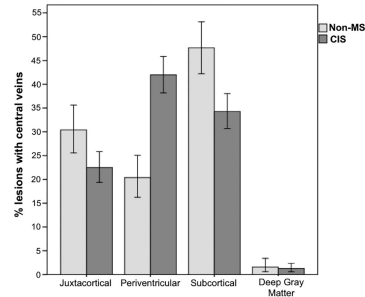


FIG 3. The location of lesions with central veins in the CIS and non-MS groups. Error bars represent standard error.

Clarke et al., 2020; n(CIS) = 112 (94 entwickelten MS, 84%), n(¬MS / MS mimics) = 35

(Differential-) Diagnostischer Wert der Läsionen mit CVS

- **CVS: nicht pathognomisch für MS**
- **~ 40 % - „Regel“¹**
- **35 % Cut-Off²: 68.1 % Sensitivität, 82.9 % Spezifität**
- **45 % Cut-Off³: 97 % Sensitivität, 99 % Spezifität; individuelles Optimum 30 – 67 %**

¹Tallantyre et al., Investigative Radiology 2009; ²Sinnecker et al., JAMA Neurol 2019; ³Suh et al., Scientific Reports 2019

Einschluß CVS in künftige modifizierte DIS-Kriterien?

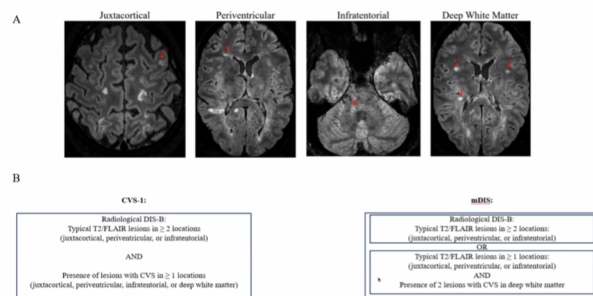


Fig. 2. (A) Lesions with central vein sign (CVS) shown in various locations. (B) Optimal incorporation of CVS into radiological rules for dissemination in space (DIS).

Amin et al., MSARD 2025

CVS (differential)diagnostische aber aktuell keine Rolle beim MS-Verlaufs- bzw. Therapie-Monitoring

Komorbiditäten?
ältere Pat. mit neuen entz. oder mikroangiopathischen Läsionen??

CVS: Zusammenfassung

Zwei bis drei Aspekte bei MS-Diagnose

- **DD der MS** (40 / 45 % Regel)
- **RIS mit DIS+ & ≥ 6 CVS gestattet MS-Diagnose** auch ohne DIT (relative Entwicklung davon + von Klinik) sowie ohne OKB/kFLC im Liquor
- **Nicht Teil der erwarteten McDonald-Revision: Modifizierte Kriterien der DIS** (mDIS: nur 1 typische T2L + ≥ 2 mit CVS in tiefer weißer Substanz)

PRLs – welche Bedeutung?

- **Diagnostischer** (aber ebenfalls nicht pathognomischer, in bis zu 50% der MS-Fälle mit Schüben oder PIRA vorkommender) **und**
- **Prognostischer Biomarker** (chronisch-schwelender Inflammation; prognostisch ähnlich wie kortikale Läsionen CL)

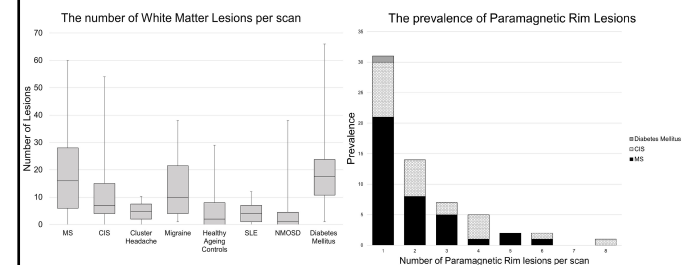
PIRA, progression independent of relapse activity
Maggi et al. Ann Neurol. 2020; La Rosa et al., NeuroImage: Clinical. 2022; Meaton et al., Mult Scler. 2022

(Differential-)Diagnostischer Wert von PRLs

- Selten bei SUSAC/SICRET, NMOSD, Sjögren, tropischer spastischer Paraparese/HTLV1-assoziiierter Myelopathie
- Dort andere Pathogenese (SUSAC/SICRET: eher Hb-Extravasation statt chronischer Inflammation?)

Maggi et al. Ann Neurol. 2020; La Rosa et al., NeuroImage: Clinical. 2022; Meaton et al., Mult Scler. 2022

(Differential-)Diagnostischer Wert von PRLs



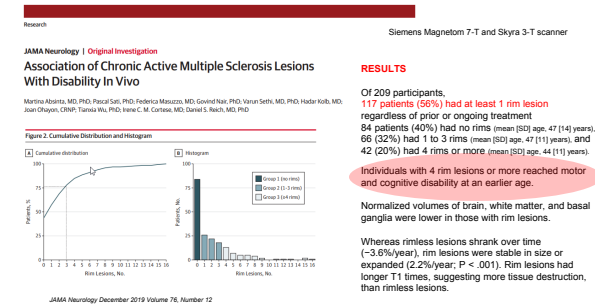
≥ 1 PRL: 26% bei CIS, 23 % bei MS; nur in ca. 1% der MS-Mimics
Spezifität: 99.7% (+CVS: 100%), Sensitivität: 24% (+CVS: 21.3%)
 für MS (n=166) + CIS (n=88) vs. MS-Mimics (n=91) + ältere Gesunde (n=217)

Meaton et al., Mult Scler. 2022

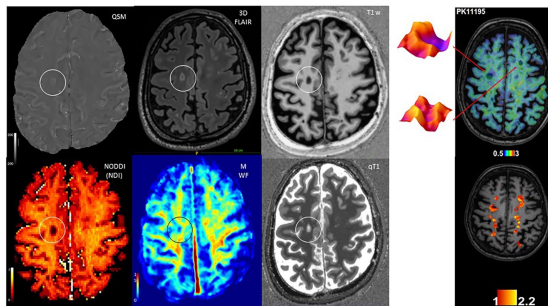
PRLs in McDonald 2024/5

- Können für MS-Diagnose genutzt werden
- Nachweis von PRLs kann die Spezifität der MS-Diagnose erhöhen
- PRL-Nachweis nicht gefordert für MS-Diagnose
- Typische Symptome + 1/5 DIS: ≥ 1 PRL + DIT oder OKB/kFLC hinreichend für MS-Diagnose

Prognostischer Wert von PRLs



Schwelende („smouldering“) PRLs = Die „wahre“ MS?

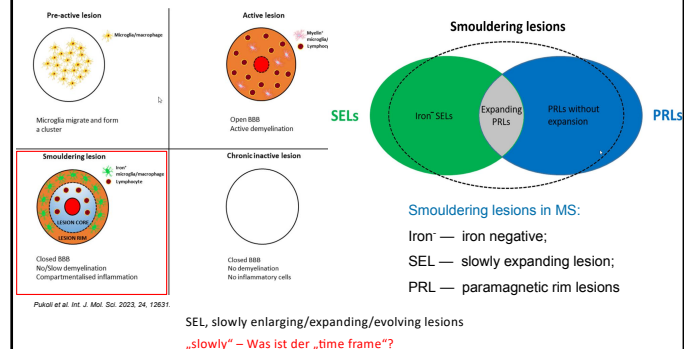


Ther Adv Neurol Disord 2022, Vol. 15: 1–18

Rechts: TSPO-Mikrogliä-PET

PRLs & Slowly Enlarging Lesions (SELs)

Veränderung der typischen Läsionsmuster im Verlauf der MS



SELs häufiger als PRLs in MS SEL-PRLs prognostisch schlecht

Calvi et al. Mult Scler. 2022

SELs in der Praxis: KH, ♀, 60 / 62 a

11/2021 06/2024 Subtraktion
aber welche?

Verlaufsdifferenz: **MAGNIMS 2021 Empfehlung** FLAIR-Subtraktionen

PD-Subtraktionen: „Aktive“ Läsionen

Moraal B et al. Ann Neurol. 2010;67:667-675.

72

How-to-do-it

MAGNETOM Flash (69) 3/2017
www.siemens.com/magnetom-world

FLAIR Fusion in Multiple Sclerosis Follow-up: An Indispensable Tool in Clinical Routine

Stéphane Cantin¹, Thomas Troalen², Emeline Lamain¹, Melisa Bakir²

¹ Groupe Clinique du Mail, Grenoble, France
² Siemens Healthineers, Saint-Denis, France

Abstract

Multiple sclerosis (MS) follow-up leads to millions of brain MRI scans around the world. Depending on the number and size of inflammatory lesions, comparing successive exams to assess dissemination in time can be a challenging and lengthy process.

This article aims to describe FLAIR image fusion with syngo.via, and to highlight the benefits in terms of new lesion detection capacity and interpretation time saving, compared to conventional frame-by-frame 3D FLAIR comparison.

Equipment

All images were acquired using a 1.5T MAGNETOM Aera system with syngo MR E11 software and the 2D-channel head coil. Postprocessing was performed using syngo.via VB10 software.

hyperintensities on FLAIR images [3]. In some cases, detecting new lesions can be relatively cumbersome and uncertain.

The common way of identifying new FLAIR hyperintensities is via the frame-by-frame comparison of successive FLAIR sequences. This can be time-consuming, especially with patients who have a high lesion load. Moreover, the comparison is very challenging with coalescing lesions, as subtle increases in size are more difficult to detect than independent new lesions.

According to the literature, the best technique appears to be the subtraction of successive FLAIR sequences [4–5]. However, tools for the co-registration and subtraction of MRI exams acquired at different time points, or even for automatic segmentation are not always available in a clinical environment [6–7].

The third technique is FLAIR fusion, which is easily

Clinical | Neurologic Imaging

MAGNETOM Flash (80) 1/2022

Update on FLAIR Fusion in Multiple Sclerosis Follow-up and Beyond: An Indispensable Tool in Clinical Routine

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¹Radiologie Bamberg, Germany
²Siemens Healthineers, Erlangen, Germany

This is an update on the article "FLAIR Fusion in Multiple Sclerosis Follow-Up: An Indispensable Tool in Clinical Routine" by Stéphane Cantin and Emeline Lamain (Groupe Clinique du Mail, Grenoble, France), and Thomas Troalen and Melisa Bakir (Siemens Healthineers, Saint-Denis, France) that was published in MAGNETOM Flash (69) 3/2017.

Background

Modern radiologists face the challenge of managing a rising number of examinations (which, with more focus on 3D imaging and multiplanar reconstructions, themselves include an increasing number of images) without compromising the quality of their reports, syngo.via offers solutions to meet this challenge.

Radiologie Bamberg is a German radiological practice with a focus on neuroradiology and inflammatory CNS diseases like multiple sclerosis (MS). In particular, its MR scanner primarily used to address the related clinical-radiological challenges is a 64-channel 3T MAGNETOM Skyra, now running on Numaris X with software version syngo MR XA30. Established core brain MR recordings for monitoring MS are a sagittal 3D FLAIR at 1 mm isotropic resolution or sagittal and axial 2D FLAIR at 3 mm slice thickness and submillimeter in-plane resolution.

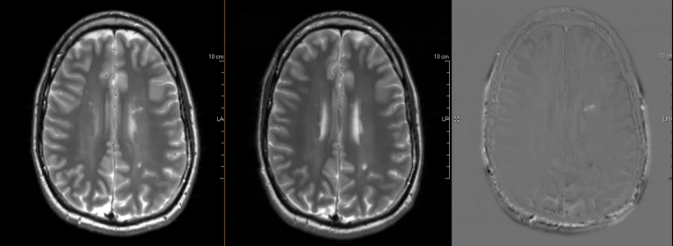
Inspired by the article "FLAIR Fusion in Multiple Sclerosis Follow-Up" by Stéphane Cantin, Thomas Troalen, Emeline Lamain, and Melisa Bakir published in MAGNETOM Flash 69 [2], we introduce further modifications, improvements and simplifications to the workflow and extend it to other applications, such as the detection of T2-progress in gliomas.

Goals

Using the previously described MPR/MIP overlay and the parathyroid-blue Color look-up table (LUT) recommended by Cantin et al. we were able to replicate their identification of new lesions. Yet, our goal and purpose for further development and improved syngo.via application was

- to fully meet and comply with the new 2021

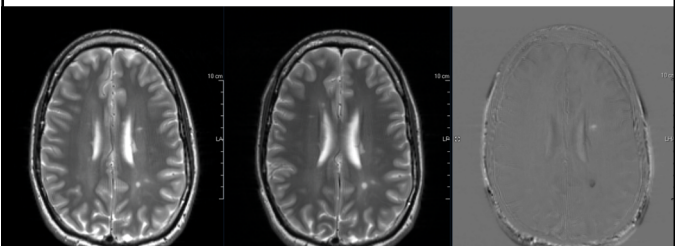
T2-Subtraktionen



MAGNETOM Flash (80) 1/2022

75

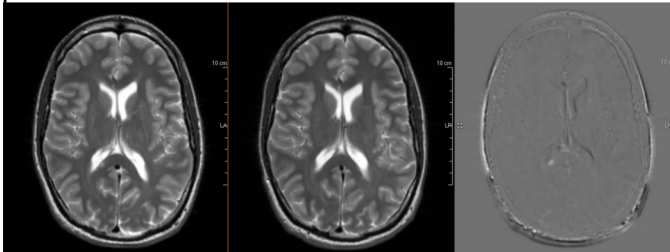
T2-Subtraktionen im Detail



MAGNETOM Flash (80) 1/2022

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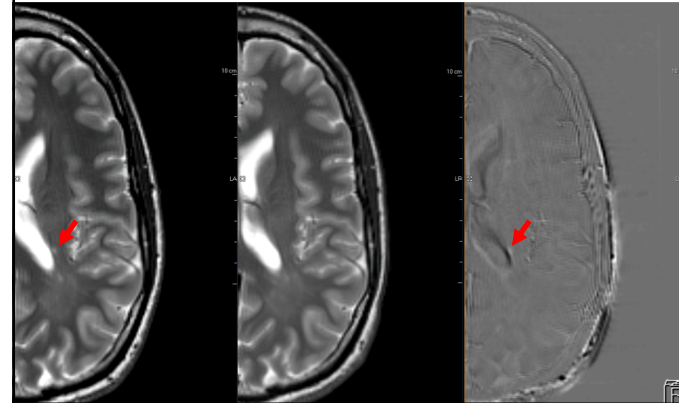
T2-Subtraktionen: Positiv- und Negativkontrast



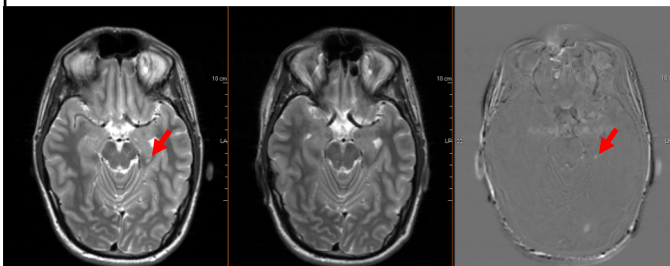
MAGNETOM Flash (80) 1/2022

77

Subtraktionen: Limits?

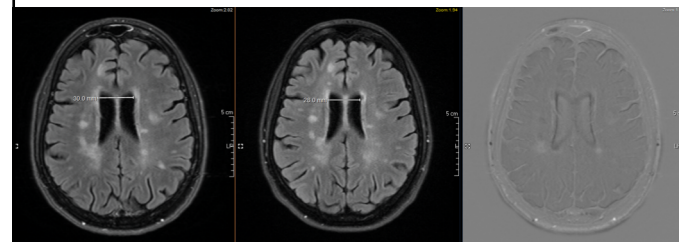


T2-Subtraktionen: Bei MS sehr hilfreich!



79

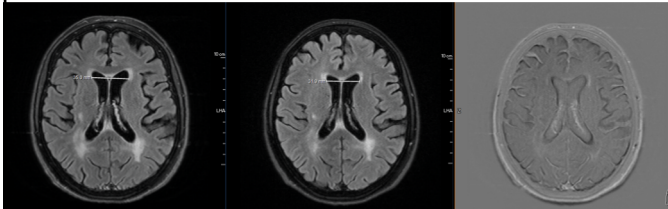
Subtraktionen und Atrophie: Ventrikelweiten



Innerhalb von fast 5a bei 61jähriger MS-Patientin

80

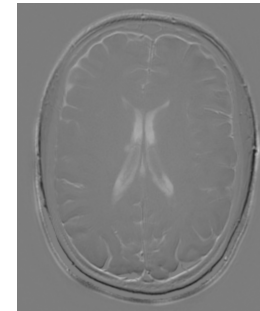
Subtraktionen und Atrophie: Ventrikel- und Furchenweiten



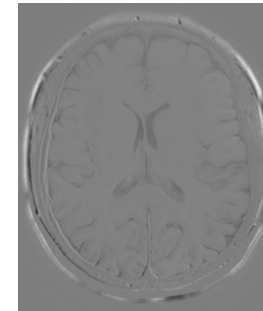
Innerhalb von fast 5a bei 77jähriger MS-Patientin

81

MS-Kontrollen mit Verlaufsdifferenzen Pitfall: Protokollunterschiede

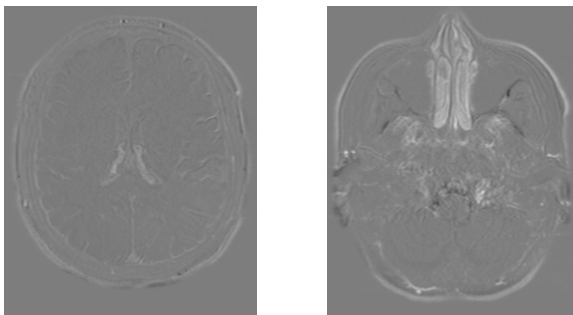


TR akt. 5.60 vs. zuvor 3.88 s,
z.B. Schichtzahl ↑; 1 NT2L



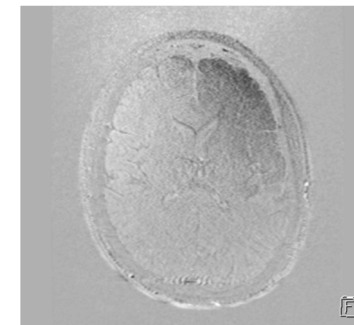
TR akt. 3.66 vs. zuvor 5.58 s,
z.B. Schichtzahl ↓

MS-Kontrollen mit Verlaufsdifferenzen Pitfall: KM-Effekt



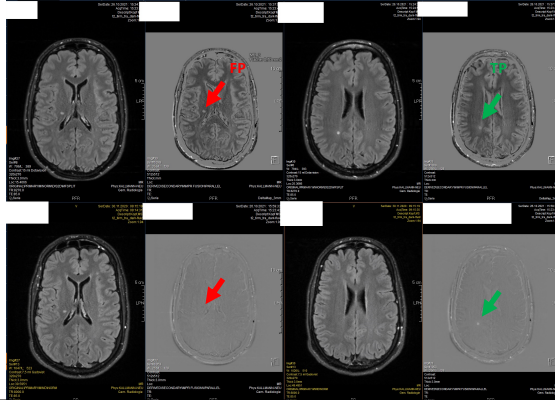
hier: FLAIR

Subtraktionen: Was u.a. schiefgehen kann ...

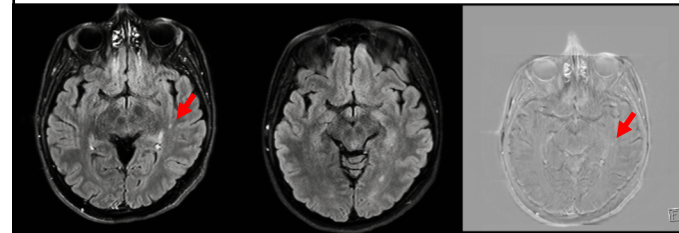


84

Subtraktionen: Was auch schiefgehen kann ...

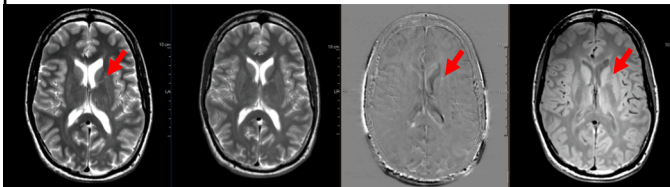


Subtraktionen: TP vs. FP-Detektionen



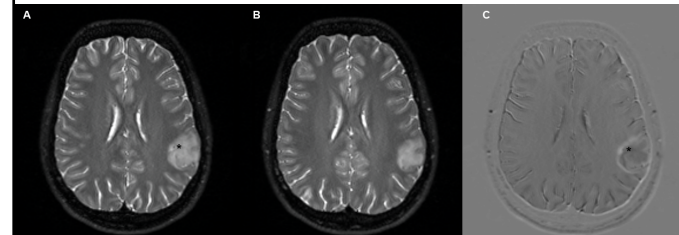
86

Subtraktionen: TP vs. FP-Detektionen



87

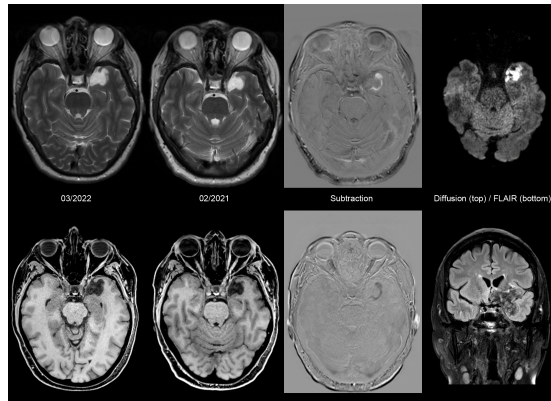
Subtraktionen: Nicht nur für MS – Beispiel T2-Gliom-Progress



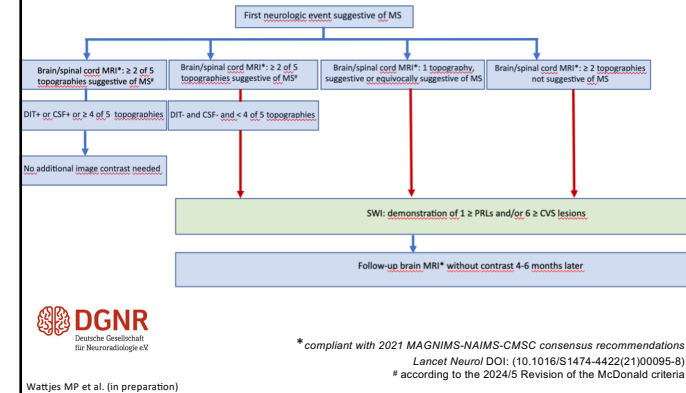
88

Subtraktionen: Nicht nur für MS – Beispiel Epidermoidwachstum

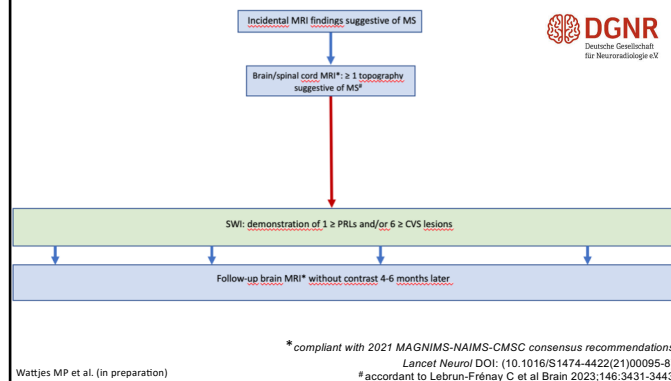
klinisch Mydriasis durch Opticomyelitis interna



SWI-MRT Flowchart: Wann bei CIS zur MS-Diagnose?



SWI-MRT Flowchart: Wann bei RIS zur MS-Diagnose?



McD-Revision 2025 & MS-VLK Herausforderungen:

- **ON#-MRT (5. DIS-Top.):** Qualität, Verfügbarkeit, Sensitivität: *Parallele zum Myelon?*, FN bei ON-MRT/OCT/VEP?
- **CVS:** ggf. mühsam zu zählen, KI?; ≥ 6 gute Wahl?, CVS-2/mDIS?
- **PRLs:** Klassifikation & Detektion
- **SWI für CVS & PRLs:** Verfügbarkeit, Qualität, zus. Scan- & Nachbearbeitungszeit (Subtrakt.)

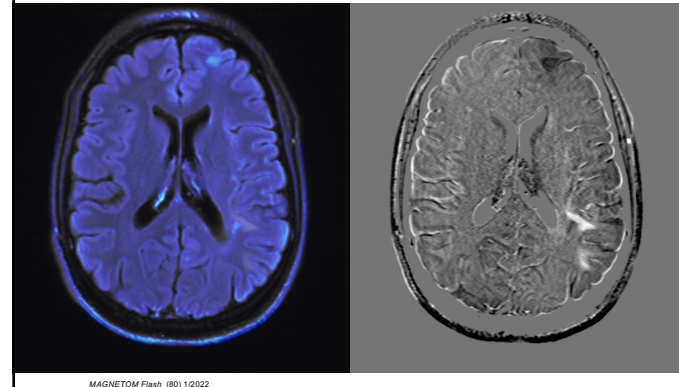
McD-Revision 2025 & MS-VLK

Möglichkeiten / Gefahren / Fragen:

- **ON[#]-MRT (5. DIS-Top.):** Sens.↑ / Spez.↓?,
ON-MRT ≠ cMRT;
- **CVS & PRLs:** wird SWI angenommen & korrekt
(mit Phasenreko) durchgeführt?, FN/FP im realen Feld?;
RIS mit z.B. 6 CVS = MS?; TA & Befundungszeit?
- **SELS /SEL-PRLs:** zuverlässig detektierbar?,
PIRA-Korrelat?, progn. Marker?; KI-Postprocessing?
- **DIT, Atrophiebewertung & -evolution:**
weniger im Fokus?; für Atrophie: KI-Postprocessing?

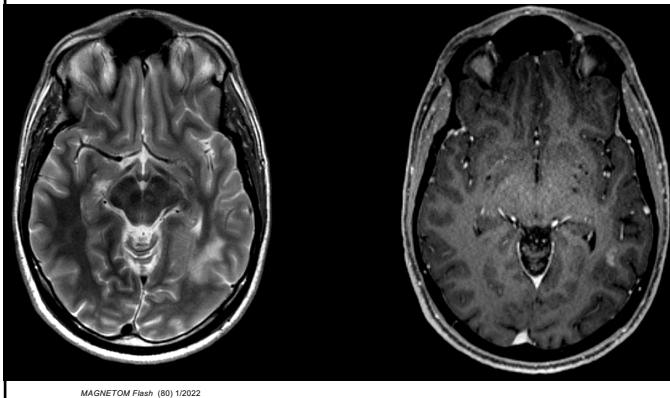
→ **Ressourcen, Vergütung?**

MS-Kontrollen mit Verlaufsdifferenzen Farboverlays vs. SW-Subtraktion



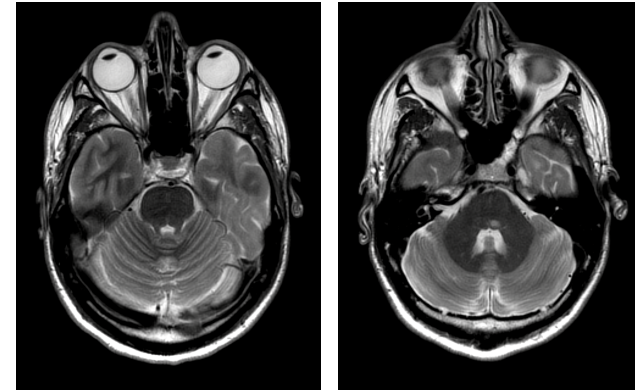
MAGNETOM Flash (80) 1/2022

Die Diagnose ist ? (i) PML !

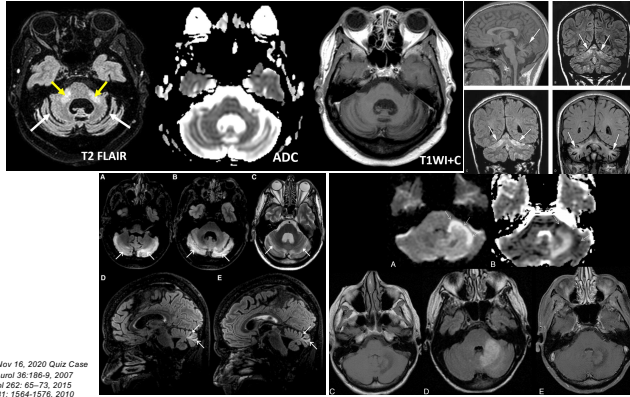


MAGNETOM Flash (80) 1/2022

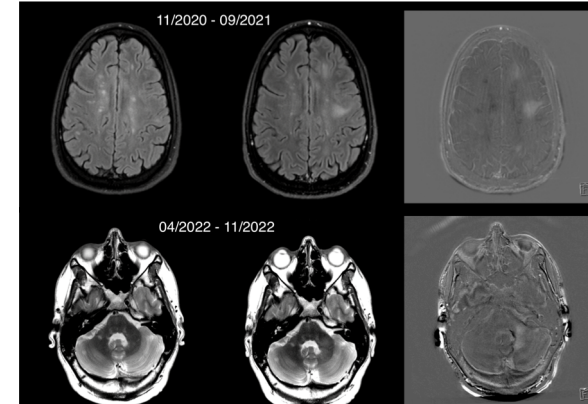
Nukleärer Abduzenzlinks !



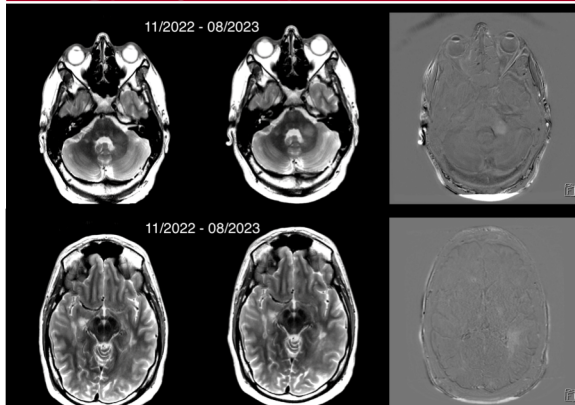
JCV-GCNP: Selten aber auch zu beachten!



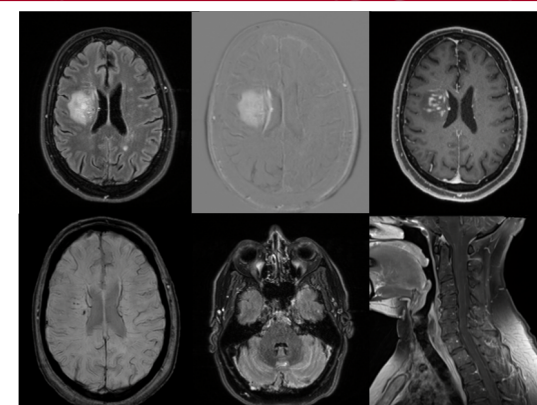
Rätselhafte Fälle (I) ♂, 32 a, ED 2020, 1a Tysabri, ab 12/21 Aubagio 14mg/d, Liquor **JCV-neg., Beinparese re, PML-s-IRIS / JCV-GCNP ?**



Rätselhafte Fälle (I) ♂, 32 a, ED 2020, 1a Tysabri, ab 12/21 Aubagio 14mg/d, Liquor **JCV-neg., Beinparese re, PML-s-IRIS / JCV-GCNP ?**



Rätselhafte Fälle (II) ♀, 59 a, ED vor 6a, Kesimpta seit 6 Mo (davor Copaxone, Aubagio + Ocrevus), seit 1.5 Wo Schwindel, gangunsicher, Fieber?



**Danke für Ihre Zeit und
Aufmerksamkeit!**