2015.02.13 第29回神奈川MRI技術研究会

造影剤とMRI検査

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contents

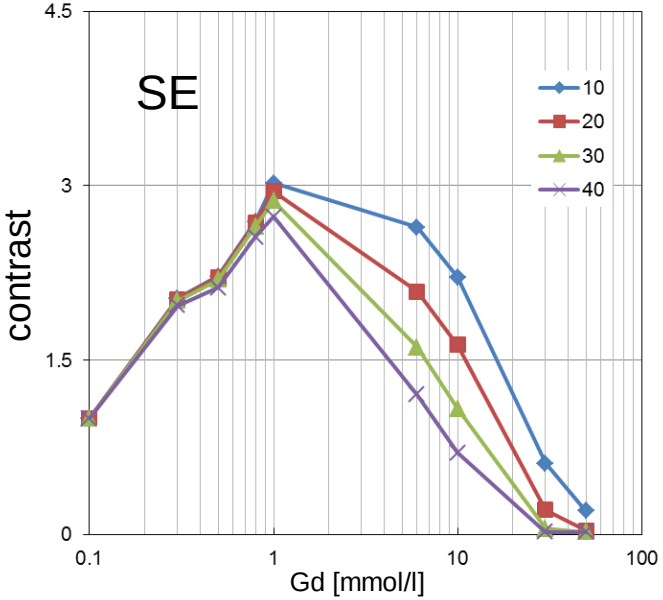
- 造影剤とシーケンス
- 造影検査の役割
- 造影剤と静磁場強度
- 造影剤開発動向　過去と現在
- DCE-permeability

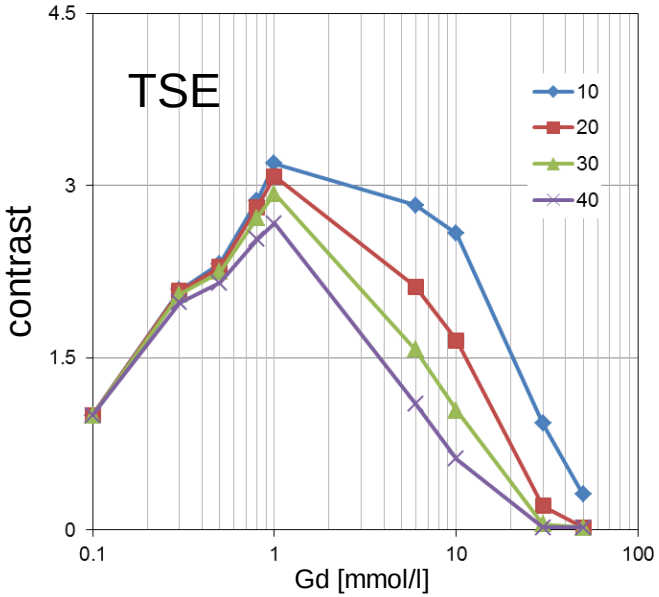
＊　今回は、安全性に関する内容はありません。

造影剤とシーケンス

TEの影響

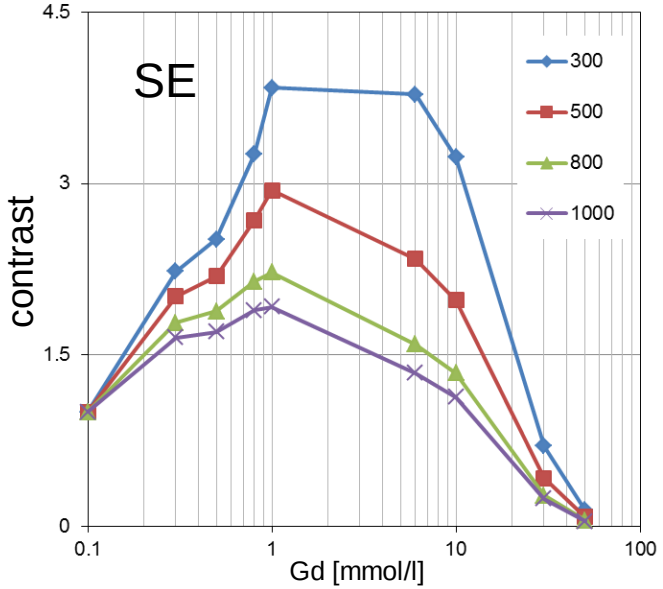
（TR 500ms）

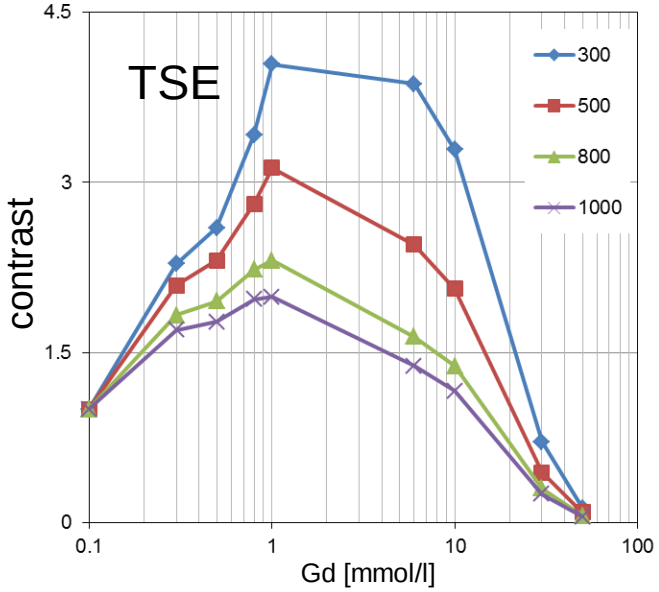




TRの影響

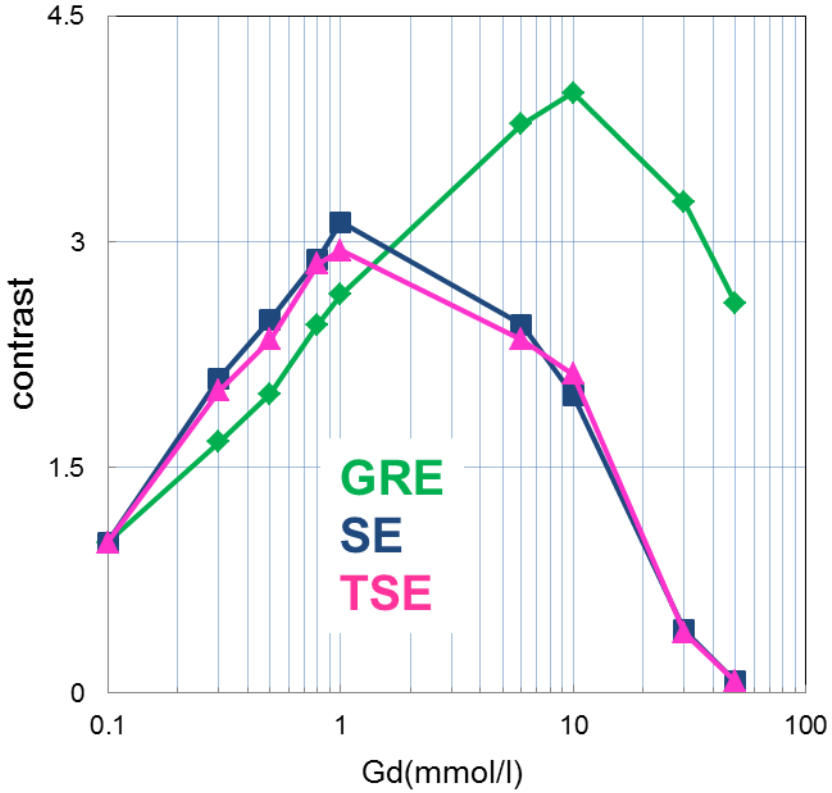
（TE 15ms）

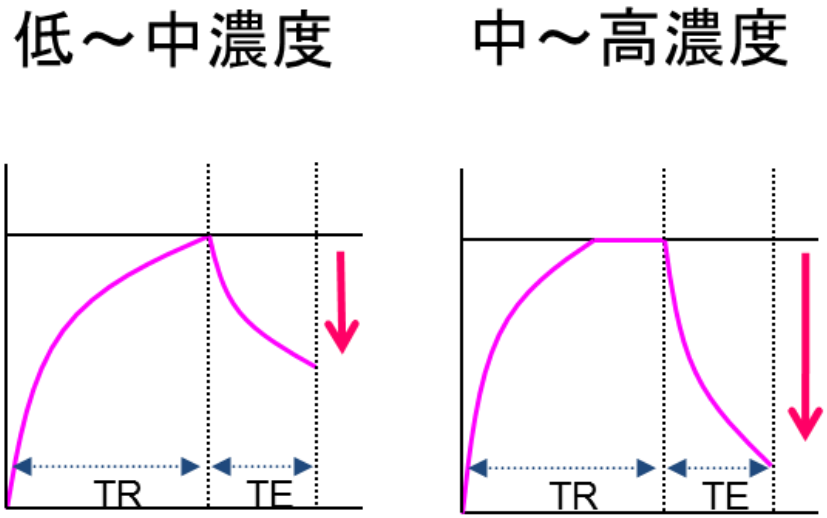




造影剤とシーケンス

用いる部位・対象組織によっても異なる。だから調べましょう。





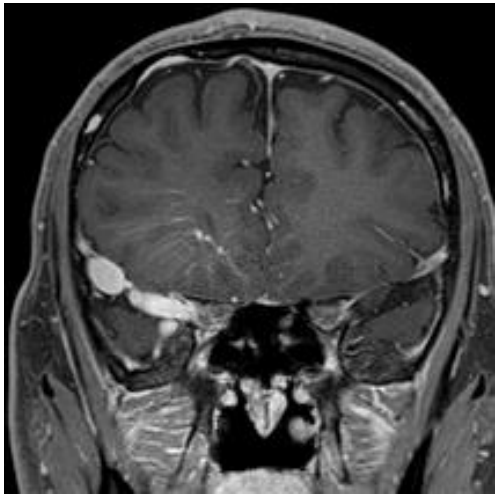
TR TEともに短くすることが必要

フック現象
造影剤濃度と信号強度は正比例しない。
高濃度では、T2短縮効果が著明になり信号強度は減少する。
GREは、SE TSEに比べその減少は小さい。

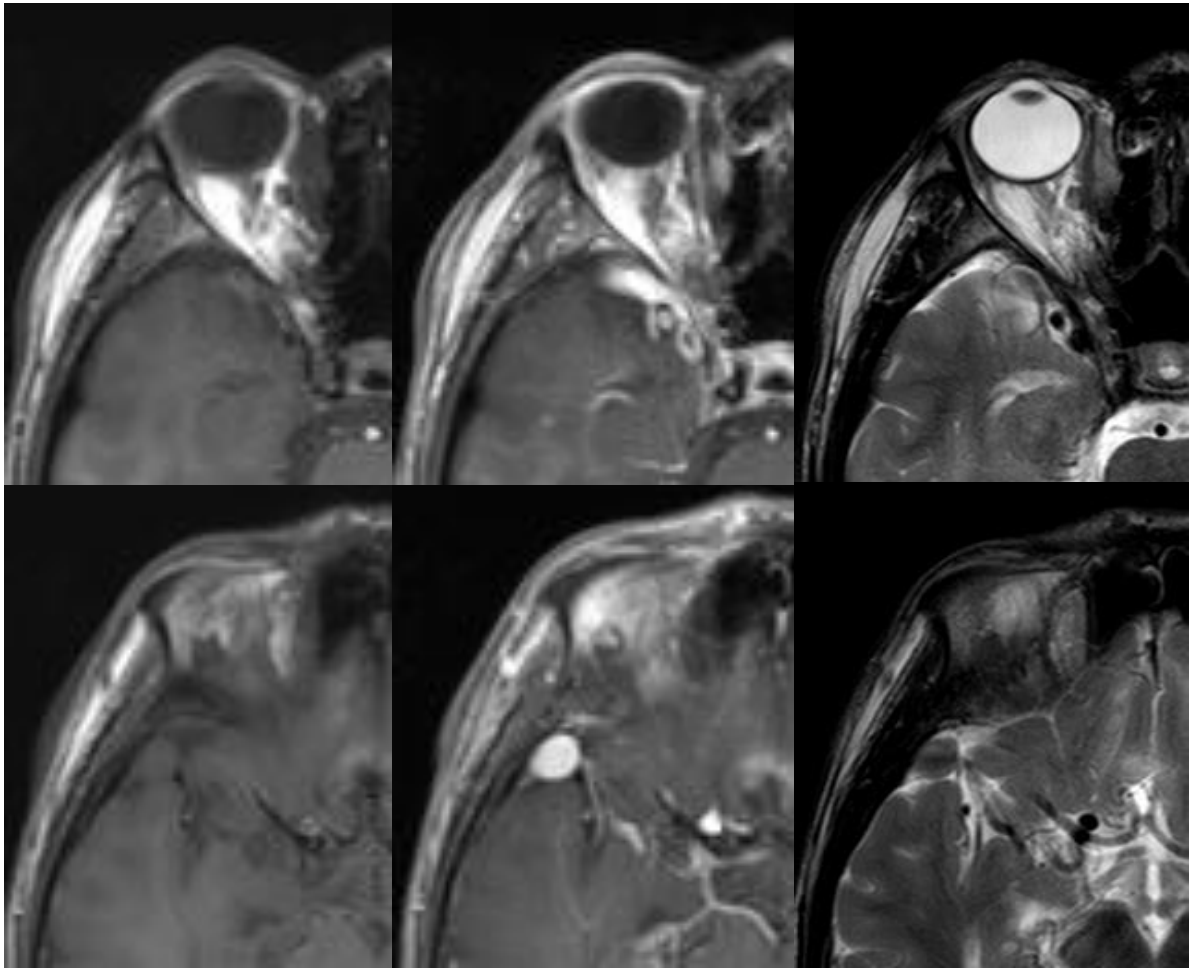
造影剤は、やはり すごい。

右眼窩血管腫
静脈奇形

Gd-FST1WI GRE



T1WI SE　Gd-T1WI SE　T2WI TSE



拡張した静脈　うっ滞しているのでflow voidになりにくい。

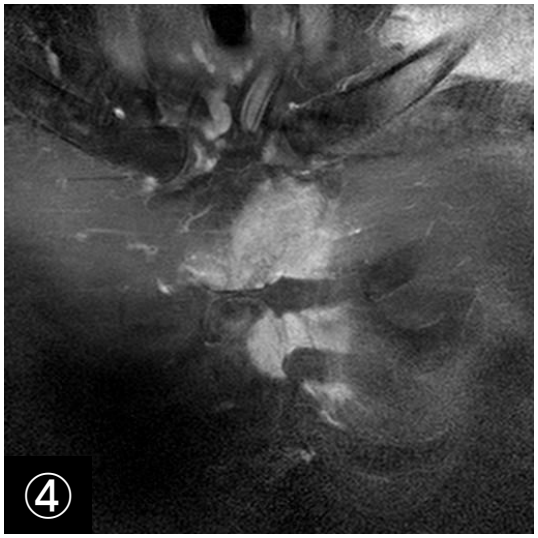
造影前後で信号は

① FST2WI（STIR）で見つける

② 造影前 T1WI で ”low”

③ 造影後 T1WIで “high”

④ 造影後 FST1WIで
周囲を“low” にして “high”



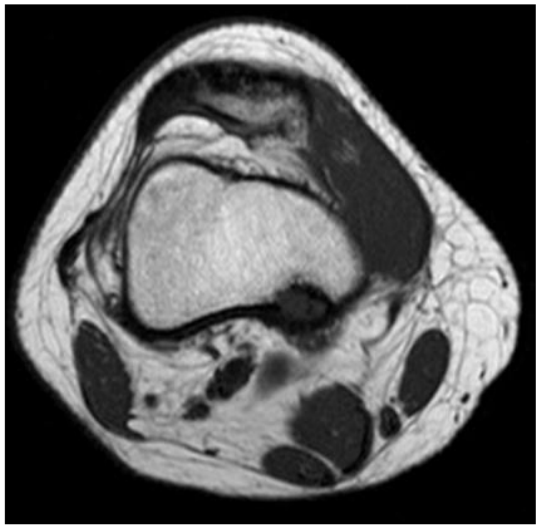
造影前後で同じものを撮る。

T1WI TSE

FST1WI TSE

造影前

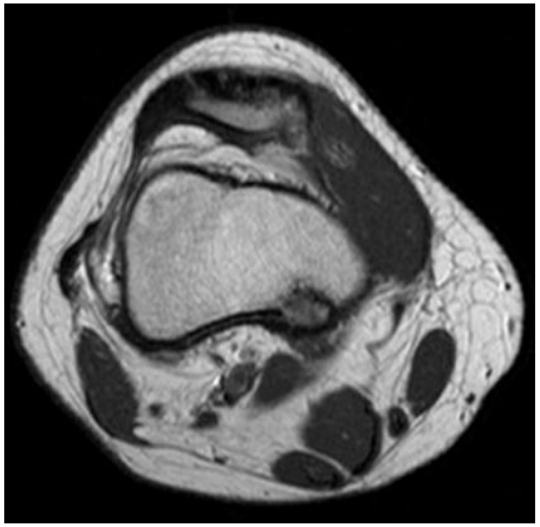
”low”

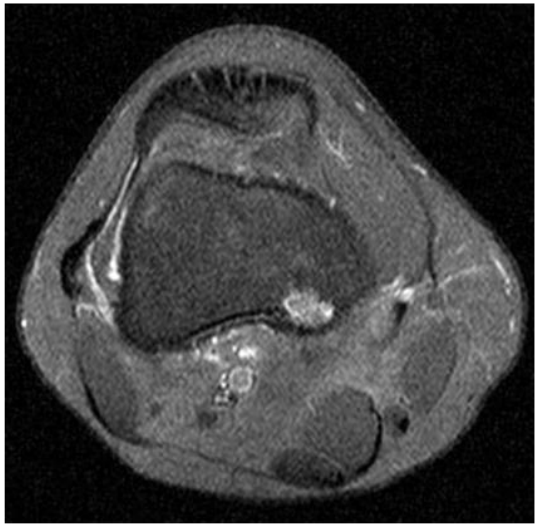


“high”

造影後

“high”

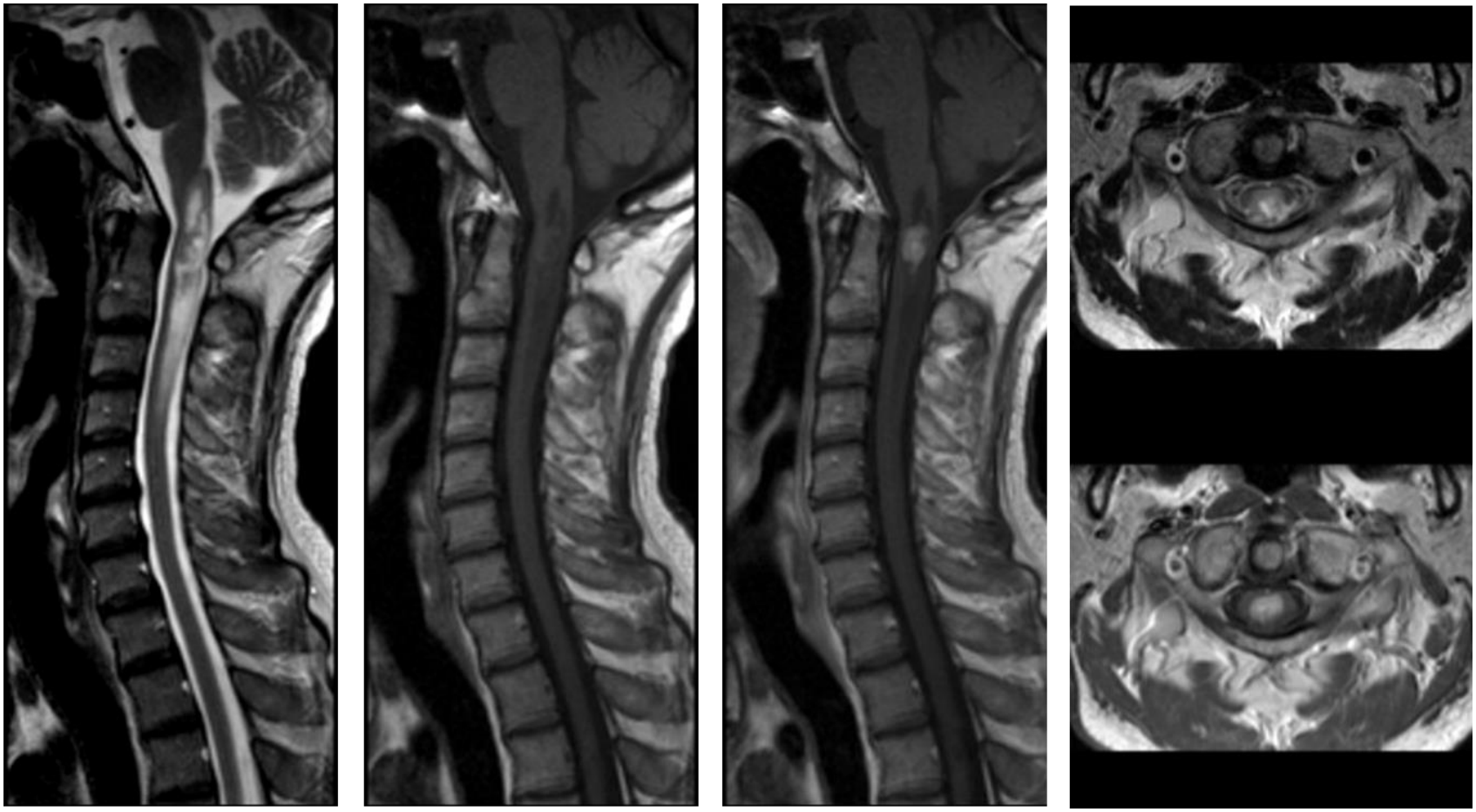




“high”
or
“low” ?

造影検査の役割

脊髄腫瘍（神経膠腫）では、悪性度評価よりは検出能向上に



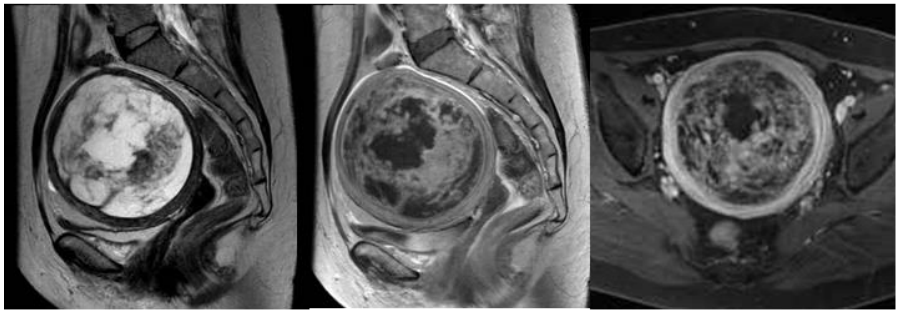
神経膠腫では、悪性度と画像所見はさまざまである。

造影検査の役割

T2WIで高信号を示す筋腫

	T1WI	T1WIGd
浮腫	等信号	中等度～高度
粘液性変性	低～等信号	（－）～軽度
嚢胞性変性	低～等信号	（－）
赤色変性	辺縁高信号	（－）
＜特殊型＞		
Cellular leiomyoma	等信号	高度
lipoleiomyoma	高信号	脂肪以外の部 中等度

子宮平滑筋腫

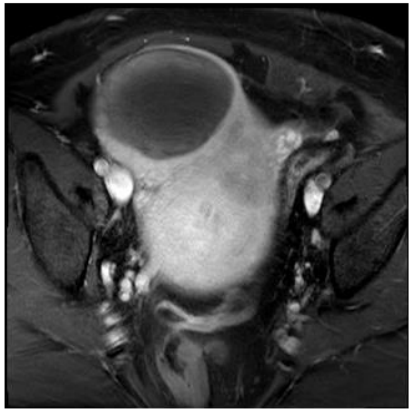


T2WI　T1WIGd　FST1WIGd

赤色変性

T2WI

T1WI



FST1WI Gd

T1WI Gd

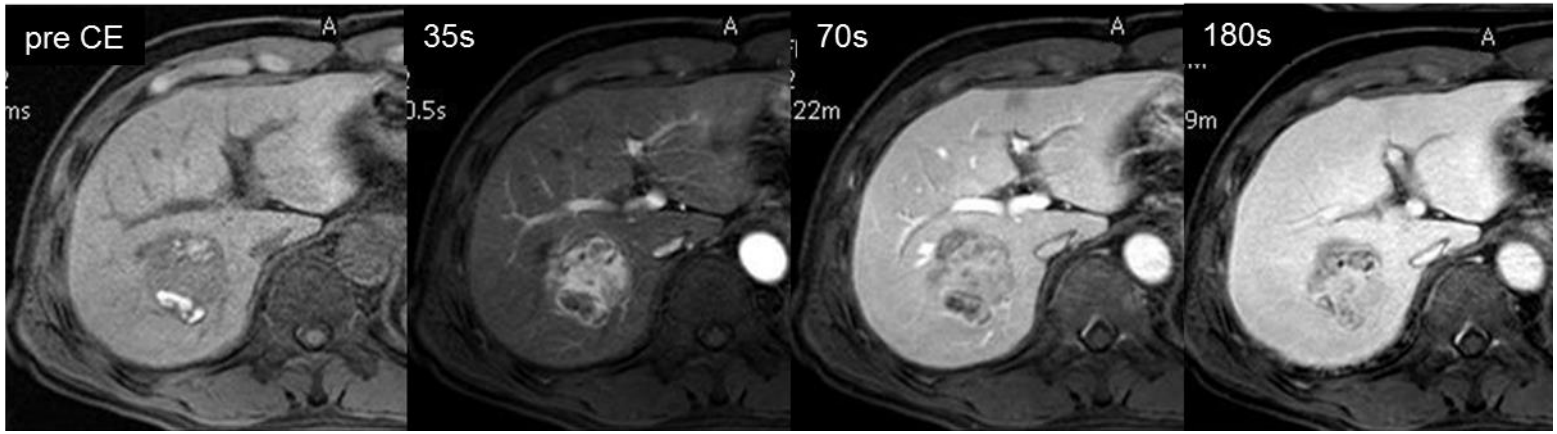
出血・壊死像が認められる。

造影検査の役割

dynamic study

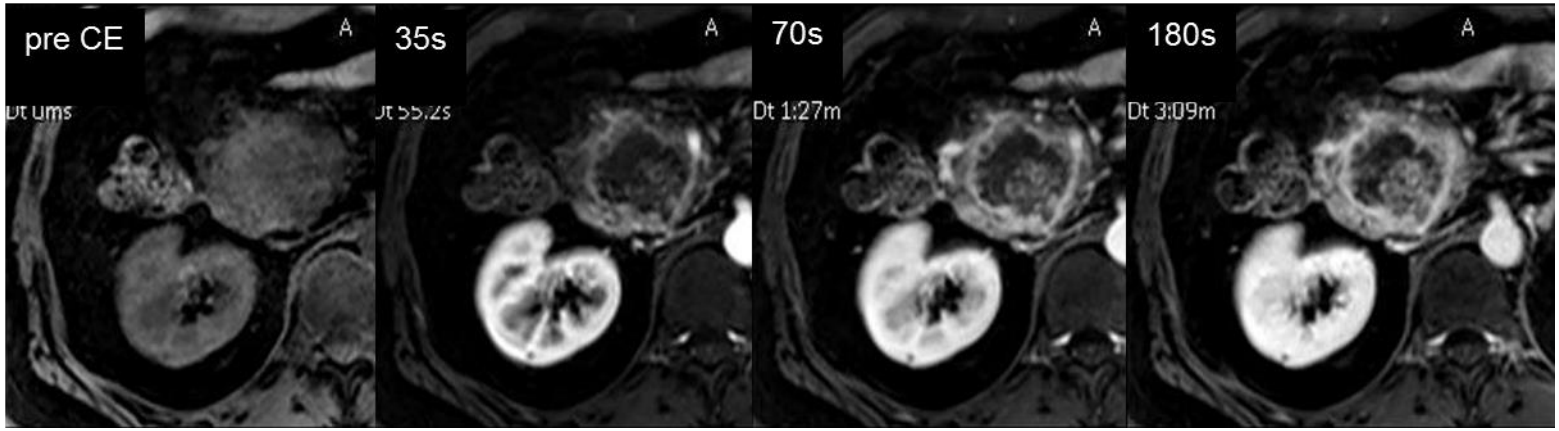
- 早く染まる。 wash out

中～高分化型HCC疑い



- ゆっくり遅く染まる。

膵頭部癌

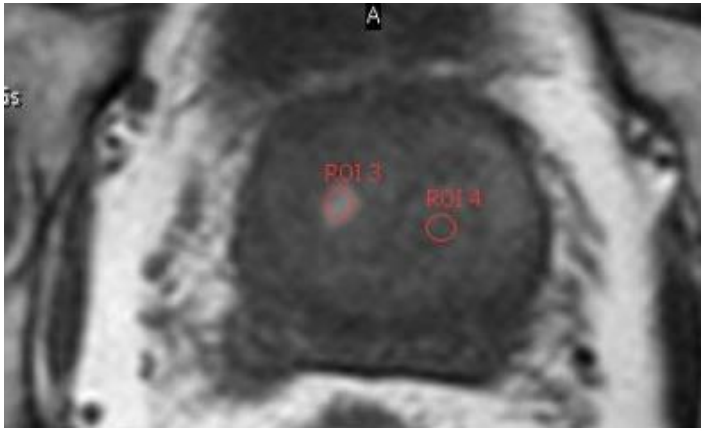


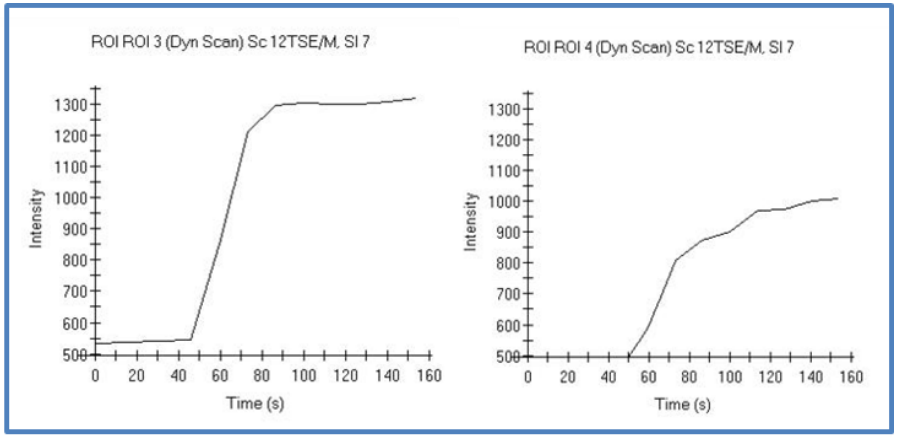
造影検査の役割

dynamic study

- 早く染まる。

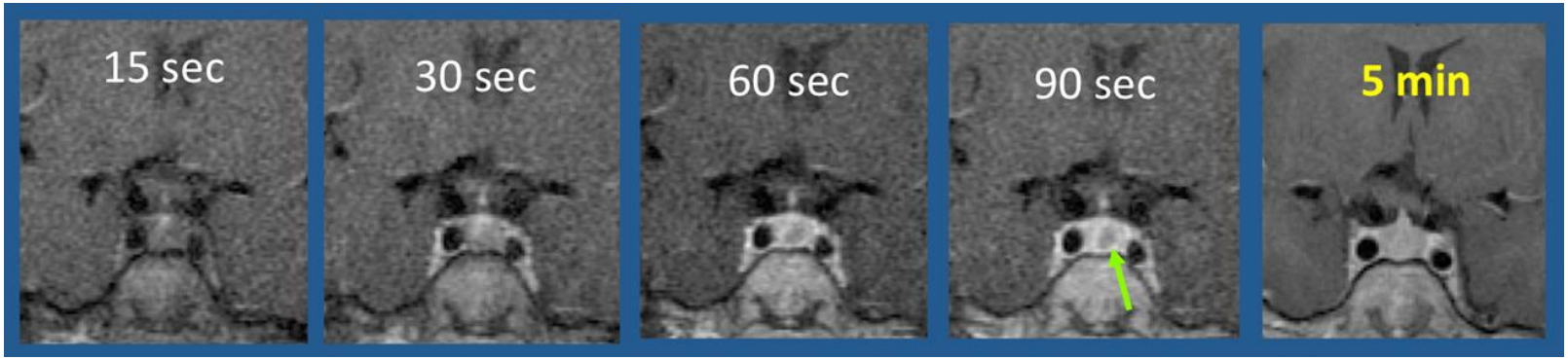
前立腺癌





- ゆっくり遅く染まる。

下垂体腺腫



造影検査の役割　　臨床進行期分類

子宮体癌　筋層浸潤の評価

- T2強調画像の junctional zone

  年齢・ホルモン療法・月経周期により描出不良あり

- dynamic 早期相　SEE（subendometrial enhancement）

  正常内膜と筋層境界に一層の増強効果　時間的にも個人差あり

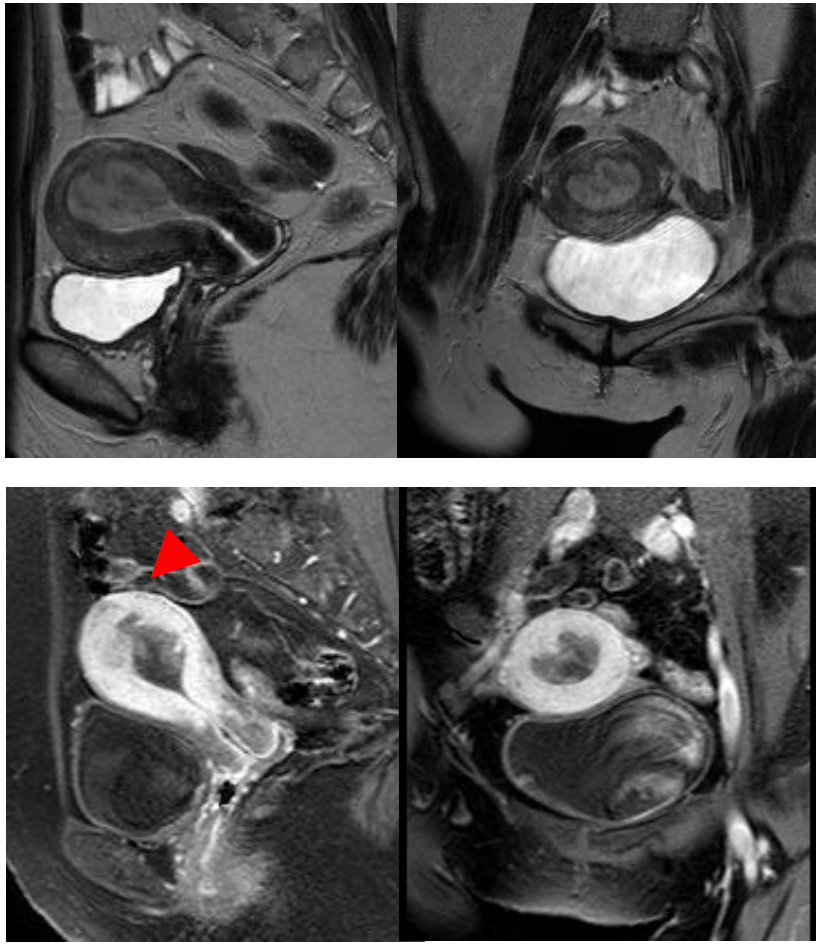
- 造影後（平衡相）腫瘍と筋層のコントラスト

  造影2分後、腫瘍とのコントラストが最大
  （体癌は筋層に比べ低信号）

  造影後は速やかに撮像することが重要
  （膀胱内への造影剤到達前に）

造影検査の役割

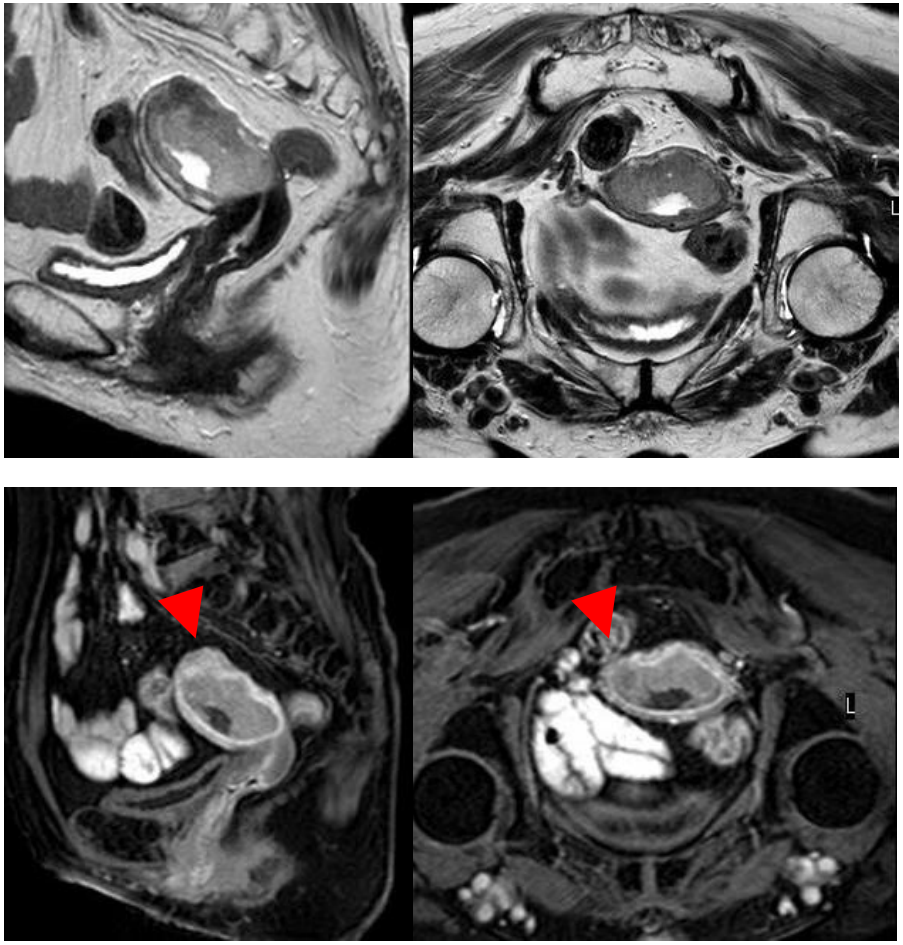
子宮体癌　Ib or Ic 58歳



子宮底部後壁にjunctional zoneが不鮮明
筋層浸潤　1/2にかかる部分もある

臨床進行期分類

子宮体癌　Ic　74歳

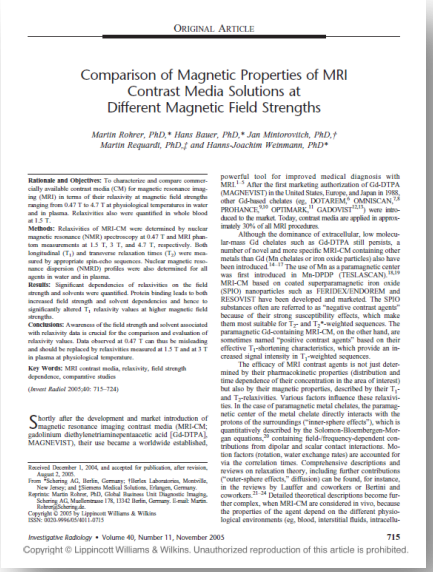


SEEの断裂あり　　dynamic 早期相

静磁場強度と緩和能（度）

Comparison of Magnetic Properties of MRI Contrast Media Solutions at Different Magnetic Field Strengths

Martin R et.al Investigative Radiology 40(11) 715-724. 2005.



ORIGINAL ARTICLE

Comparison of Magnetic Properties of MRI Contrast Media Solutions at Different Magnetic Field Strengths

Martin Rohrer, PhD, Hans Bauer, PhD,* Jan Mintorovitch, PhD,† Martin Requardt, PhD,‡ and Hanns-Joachim Weinmann, PhD**

Rationale and Objectives: To characterize and compare commercially available contrast media (CM) for magnetic resonance imaging (MRI) in terms of their relaxivity at magnetic field strengths ranging from 0.47 T to 4.7 T at physiological temperatures in water and in plasma. Relaxivities also were quantified in whole blood at 1.5 T.

Methods: Relaxivities of MRI-CM were determined by nuclear magnetic resonance (NMR) spectroscopy at 0.47 T and MRI phantom measurements at 1.5 T, 3 T, and 4.7 T, respectively. Both longitudinal (T_1) and transverse relaxation times (T_2) were measured by appropriate spin-echo sequences. Nuclear magnetic resonance dispersion (NMRD) profiles were also determined for all agents in water and in plasma.

Results: Significant dependencies of relaxivities on the field strength and solvents were quantified. Protein binding leads to both increased field strength and solvent dependencies and hence to significantly altered T_1 relaxivity values at higher magnetic field strengths.

Conclusions: Awareness of the field strength and solvent associated with relaxivity data is crucial for the comparison and evaluation of relaxivity values. Data observed at 0.47 T can thus be misleading and should be replaced by relaxivities measured at 1.5 T and at 3 T in plasma at physiological temperature.

Key Words: MRI contrast media, relaxivity, field strength dependence, comparative studies

(*Invest Radiol* 2005;40: 715–724)

Shortly after the development and market introduction of magnetic resonance imaging contrast media (MRI-CM; gadolinium diethylenetriaminepentaacetic acid [Gd-DTPA], MAGNEVIST), their use became a worldwide established, powerful tool for improved medical diagnosis with MRI.[1–3] After the first marketing authorization of Gd-DTPA (MAGNEVIST) in the United States, Europe, and Japan in 1988, other Gd-based chelates (eg, DOTAREM,[4] OMNISCAN,[5,6] PROHANCE,[7,8] OPTIMARK,[9] GADOVIST[10,11]) were introduced to the market. Today, contrast media are applied in approximately 30% of all MRI procedures.

Although the dominance of extracellular, low molecular-mass Gd chelates such as Gd-DTPA still persists, a number of novel and more specific MRI-CM containing other metals than Gd (Mn chelates or iron oxide particles) also have been introduced.[14–17] The use of Mn as a paramagnetic center was first introduced in Mn-DPDP (TESLASCAN),[18,19] MRI-CM based on coated superparamagnetic iron oxide (SPIO) nanoparticles such as FERIDEX/ENDOREM and RESOVIST have been developed and marketed. The SPIO substances often are referred to as "negative contrast agents" because of their strong susceptibility effects, which make them most suitable for T_2- and T_2*-weighted sequences. The paramagnetic Gd-containing MRI-CM, on the other hand, are sometimes named "positive contrast agents" based on their effective T_1-shortening characteristics, which provide an increased signal intensity in T_1-weighted sequences.

The efficacy of MRI contrast agents is not just determined by their pharmacokinetic properties (distribution and time dependence of their concentration in the area of interest) but also by their magnetic properties, described by their T_1- and T_2-relaxivities. Various factors influence these relaxivities. In the case of paramagnetic metal chelates, the paramagnetic center of the metal chelate directly interacts with the protons of the surroundings ("inner-sphere effects"), which is quantitatively described by the Solomon-Bloembergen-Morgan equations,[20] containing field-frequency-dependent contributions from dipolar and scalar contact interactions. Motion factors (rotation, water exchange rates) are accounted for via the correlation times. Comprehensive descriptions and reviews on relaxation theory, including further contributions ("outer-sphere effects," diffusion) can be found, for instance, in the reviews by Lauffer and coworkers or Bertini and coworkers.[21–24] Detailed theoretical descriptions become further complex, when MRI-CM are considered in vivo, because the properties of the agent depend on the different physiological environments (eg, blood, interstitial fluids, intracella-

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Table 4 Relaxivities* of investigated Contrast Media in Plasma at 37°C

	0.47T**		1.5T		3.0T		4.7T	
	r1	r2	r1	r2	r1	r2	r1	r2
MAGNEVIST	3.8	4.1	4.1	4.6	3.7	5.2	3.8	4.8
GADOVIST	6.1	7.4	5.2	6.1	5	7.1	4.7	5.9
PROHANCE	4.8	6.1	4.1	5	3.7	5.7	3.7	5.8
OMUNISCAN	4.4	4.6	4.3	5.2	4	5.6	3.9	5.3
RESOVIST	15	101	7.4	95	3.3	160	1.7	118
PRIMOVIST	8.7	13	6.9	8.7	6.2	11	5.9	12

* Values in L $mmol^{-1}s^{-1}$ ** Measured at 40°C

静磁場強度の違いにおけるT1 T2の変化

	T_1 (ms)			T_2 (ms)		
	1.5T	3.0T	増加率（%）	1.5T	3.0T	増加率（%）
腎皮質	966±58	1142±154	18	87±4	76±7	-13
肝臓	586±39	809±71	38	46±6	34±4	-26
脾臓	1057±41	1328±31	26	79±15	61±9	-23
膵臓	584±14	725±71	24	46±6	43±7	-7
傍脊椎筋	856±61	898±33	5	27±8	29±4	7
骨髄	549±52	586±73	7	49±8	49±4	1
皮下脂肪	343±37	382±13	11	58±4	68±4	17
子宮筋層	1309±35	1514±156	16	117±14	79±10	-33
子宮内膜	1274±64	1453±123	14	101±21	59±1	-42
前立腺	1317±85	1597±42	21	88±0	74±9	-16

＊de Bazelaire CMJ,et al:MR imaging relaxation times of abdominal and pelvic tissues measured in vivo at 3.0T:Preliminary results.Radiology 230:652-659,2004.

EOBにおける静磁場強度の比較　SNRとCNR

$$SNR_{right\ liver} = \frac{signal\ intensity_{right\ liver}}{S.D._{right\ liver}}$$

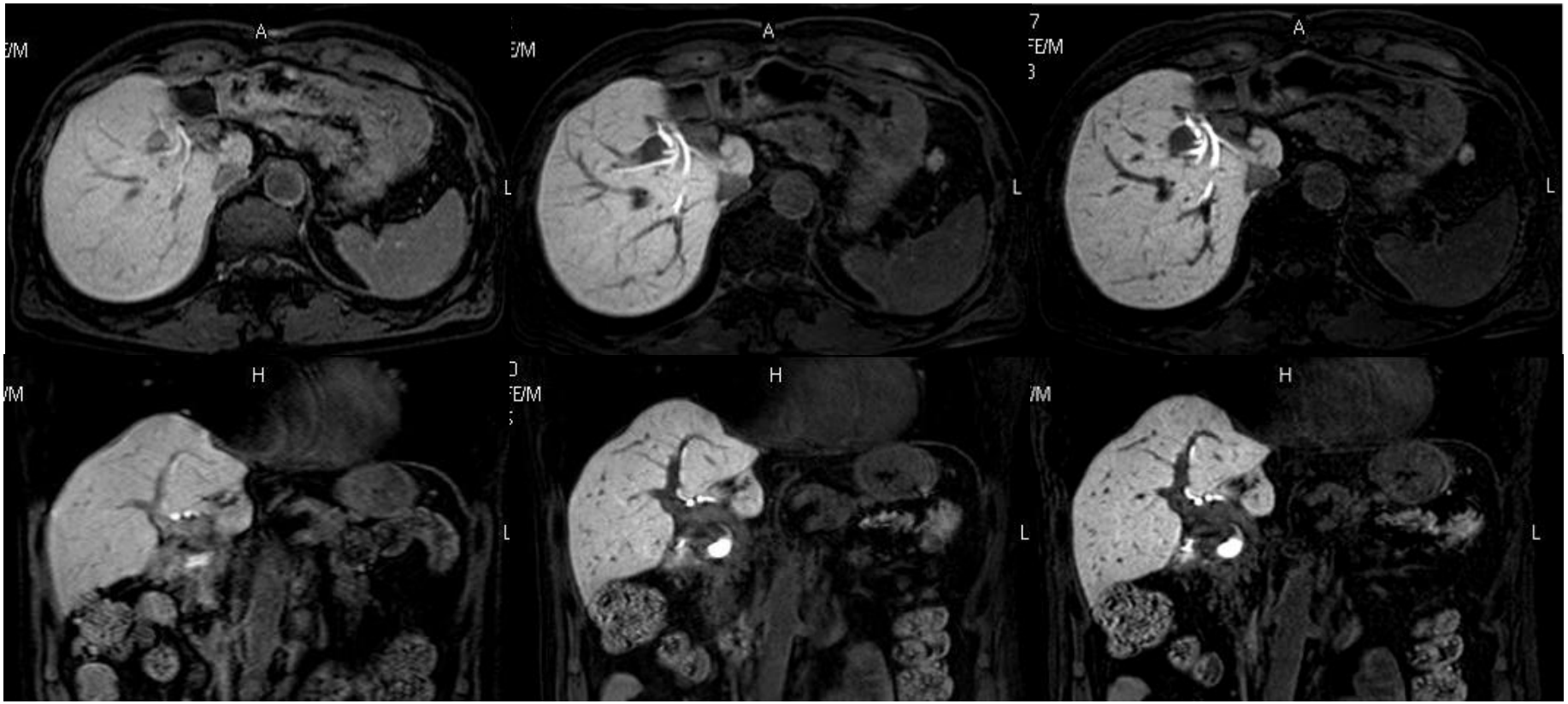
$$CNR_{right\ liver - IVC} = (SNR_{right\ liver} - SNR_{IVC})$$

ROI : 50 pixel

Post-Contrast (delay 15min) e-THRIVE	3.0T		1.5T		*P*-value	Mean gain (%)
	Mean	S.D.	Mean	S.D.		
$SNR_{right\ liver}$	31.7	10.3	26.5	8.0	0.027	19.6
$SNR_{left\ liver}$	29.2	14.0	24.5	8.6	0.045	19.2
SNR_{IVC}	12.1	4.9	18.5	5.6	0.003	34.6
$CNR_{right\ liver - IVC} = (SNR_{right\ liver} - SNR_{IVC})$	19.5	13.2	7.9	8.8	0.002	46.8
$CNR_{left\ liver - IVC} = (SNR_{left\ liver} - SNR_{IVC})$	17.1	15.8	6.0	9.1	0.004	48.5

The statistical data of quantitative analysis for SNRs and CNRs were compared between 3.0T and 1.5T using the paired samples t-test.

EOBにおける静磁場強度の比較　SNRとCNR



1.5T e-THRIVE

slices thickness : 5.0mm/-2.5mm （sliceZIP）
number of slices : 70
TR/TE/FA : 5.4/2.6/10°
scan time :22sec

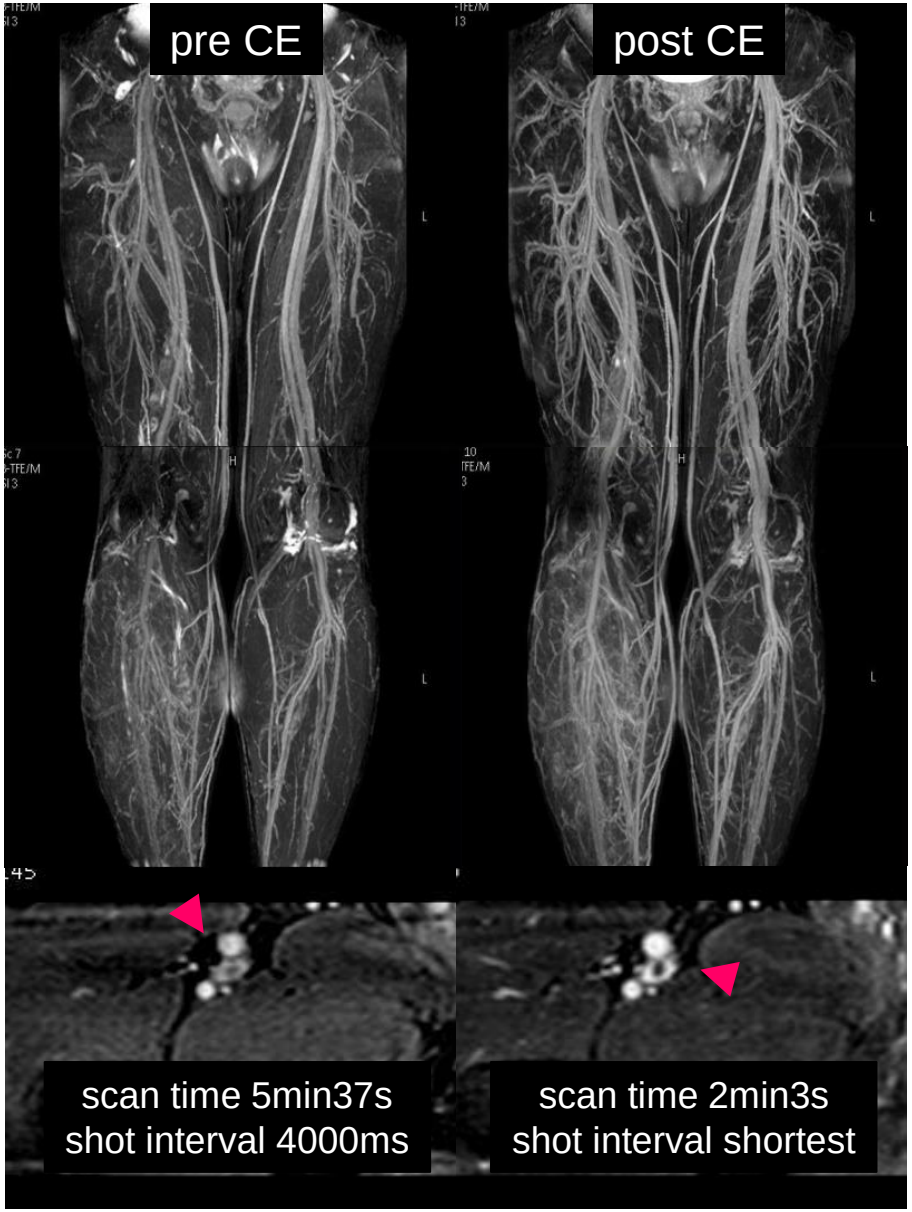
3.0T Normal e-THRIVE

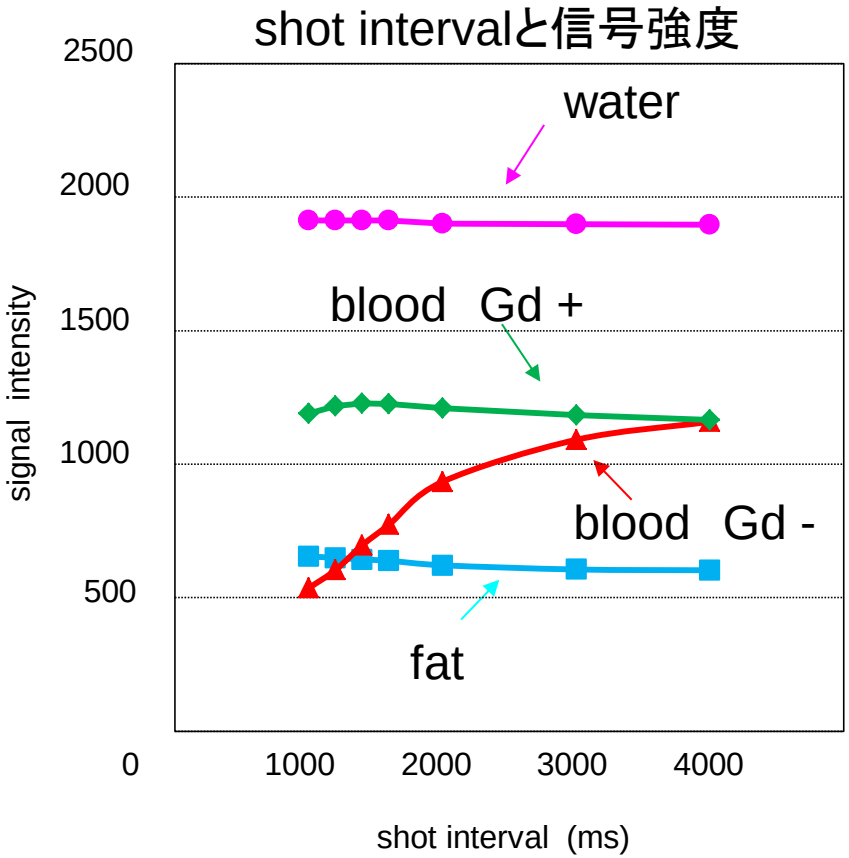
slices thickness : 5.0mm/-2.5mm （sliceZIP）
number of slices : 70
TR/TE/FA : 3.2/1.5/10°
scan time :16sec

3.0T HR e-THRIVE

slices thickness 1.7mm/-0.85mm （sliceZIP）
number of slices 200
TR/TE/FA : 3.2/1.44/10°
scan time : 23sec

造影したら、撮り方を変える。





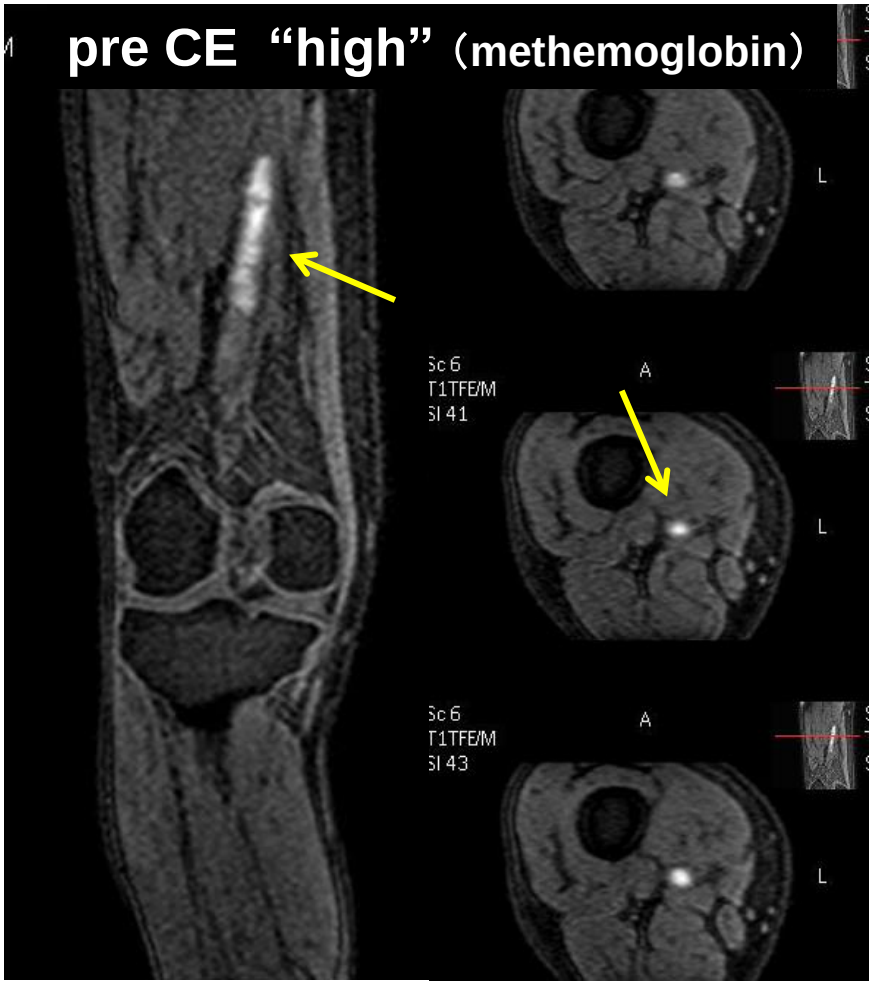
S.I.を延長すると血液は高い

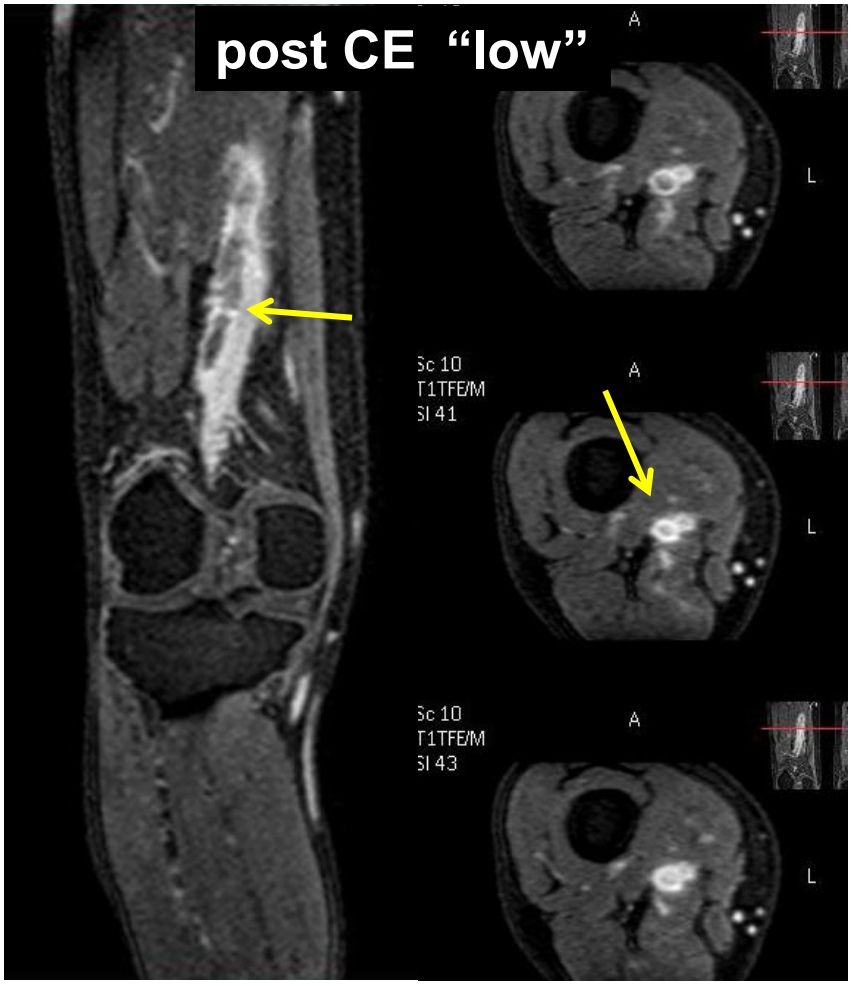
造影ではS.I.を最短でも血液は高い

造影前に ”high”　造影後に ”low”

3DFS-IRT1TFE（≒ MPRAGE）

DTI* : direct thrombus imaging

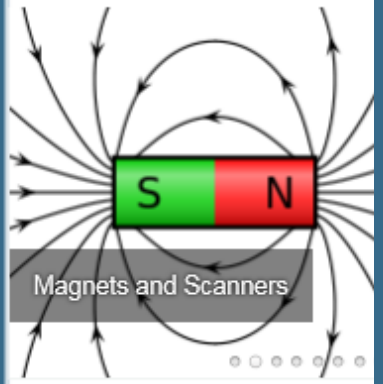




**Moody AR et al:.Direct imaging of deep-vein thrombosis with magnetic resonance imaging. Lancet 1997.

QUESTIONS AND ANSWERS IN MRI

- Home
- Complete List of Questions
- ...Magnets & Scanners
- ...The NMR Phenomenon
- ...Pulse Sequences (Basic)
- ...Making an Image
- ...K-space & Rapid Imaging
- ...Paramagnetic Contrast
- ...Cardiovascular and MRA
- ...MR Artifacts
- ...Coming Soon!
- Copyright/Legal
- What's New
- Open Forum/Discussion



Welcome to the Questions and

In 1994 I published the first edition of *Questions a*
collection of notes on MR physics I had distribute
teaching over the years. Jonathan Burdette helpe
edition appeared in 2001. These books were big h
pride how many people tell me they learned most
them.

The concept was radically different from "standar
my own creation, but were questions actually pos
they reflected areas of common confusion that ha
books and web sources.

The original paperbacks are long out of print, and
simple revision of the original material is not pos
overhaul of all my original notes, bringing the mat
multimedia and other web-enabled features. I hop

There is no charge for using this site; it is my gift
good to me. But please don't reproduce or use an
appropriate credit.

No doubt there are some errors and omissions, and I encourage anyone with suggested changes to email me or post them in the forum. I will then try to correct my answers or explain them more completely.

Yours sincerely,

Allen D. Elster MD

Allen D. Elster, MD FACR
Chair, Emeritus
Division of Radiologic Sciences
Wake Forest School of Medicine
Winston-Salem, NC 27106

- ...The NMR Phenomenon
- ...Pulse Sequences (Basic)
- ...Making an Image
- ...K-space & Rapid Imaging
- ...Paramagnetic Contrast
- ...Cardiovascular and MRA
- ...MR Artifacts
- ...Coming Soon!
- Copyright/Legal
- What's New
- Open Forum/Discussion

The observed T1 relaxation rate ($1/T1_{obs}$) caused by contrast material accumulating in a tissue is given by

$$1/T1_{obs} = 1/T1_t + r_1 \cdot [C]$$

where $1/T1_t$ is the base relaxation rate of the tissue without contrast, [C] is the concentration of contrast agent within the tissue, and r_1 is the relaxivity of the contrast agent. By algebraic rearrangement it is
in tissue relaxation due to the contrast agent:

$$) \div (1/T1_t) = T1_t \cdot r_1 \cdot [C]$$

$T1_{obs}$ can be taken as a surrogate for relative
veral features about contrast enhancement well

1. Contrast enhanceme with baseline long $T1_t$ values (i.e., tissues that are dark on T1-weig
2. More contrast [C] in ement.
3. Contrast agents with es produce stronger enhancement.

To understand how the fie trast enhancement, we must consider how $T1_t$ and r_1 each change as a f

The field-dependence of ti n discussed in a prior Q&A. In general, tissue T1 values increase with in enomenon occurs because the Larmor frequency scales with field strength and T1 relaxation requires energy exchanges near the Larmor frequency to be effective. With increasing Larmor frequencies a progressive mismatch occurs with molecular motions in solid tissues, resulting in inefficient energy transfer and longer T1 values.

- Contrast Agents: Physics > Why Gadolinium?
- Contrast Agents: Clinical > Paramagnetic relaxation?
- Contrast Agents: Safety > What is relaxivity?
- Blood: Paramagnetism > Why does Gd shorten T1?
- Does Gd affect T2?
- Gd & field strength?
- Best T1-pulse sequence?
- Triple dose and MT?
- Dynamic CE imaging?
- Gadolinium on CT?

The field dependence of gadolinium-based MR contrast agents depends on the range of field strengths considered as well as the particular agent. The table right shows T1 relaxivities for nine commercially available contrast agents.

Name	0.47T	1.5T	3.0T	4.7T
Magnevist®	3.8	4.1	3.7	3.8
MultiHance®	9.2	6.3	5.5	5.2
Omniscan™	4.4	4.3	4.0	3.9
OptiMARK™	5.7	4.7	4.5	4.4
Dotarem®	4.3	3.6	3.5	3.3
ProHance®	4.8	4.1	3.7	3.7

In general a slight decrease in r_1 is noted for all

とても有用なサイトです。
・基礎から臨床　動画
・文献もオンライン

日獨医報　50（1）114–132（2005）

MRI造影剤の過去・現在・未来

谷本　伸弘　先生

日獨医報 放射線診療の過去・現在・未来

造影剤

2．MRI造影剤の過去・現在・未来

谷本　伸弘、栗林　幸夫

慶應義塾大学医学部　放射線診療科

MR Contrast Agents: Past, Recent Trends, and Prospects

Akihiro Tanimoto, M.D. and Sachio Kuribayashi, M.D.

Department of Diagnostic Radiology, Keio University School of Medicine

NICHIDOKU-IHO
Vol. 50 No. 1 114–132 (2005)

Summary

Non-specific extracellular gadolinium chelates have been widely used in contrast-enhanced MR imaging. These agents distribute into the intravascular and interstitial spaces and differentially alter tissue contrast through relatively selective enhancement of proton relaxation based on differences in compartmentation, distribution, and residence times of the pharmaceutical. They also allow the evaluation of physiological parameters, such as the status or presence of the blood-brain-barrier or renal function.

Meanwhile, liver-specific MR contrast agents have been developed as the first tissue-specific pharmaceuticals to include superparamagnetic iron oxide (SPIO) particles and hepatobiliary paramagnetic agents. SPIO particles are phagocytosed by reticuloendothelial cells in the liver, resulting in negative enhancement of the liver parenchyma on T2- or T2*-weighted imaging. Hepatobiliary paramagnetic agents are partially taken up by hepatocytes, yielding positive sustained enhancement of the liver parenchyma on T1-weighted imaging. These agents have been demonstrated to improve the detection and characterization of hepatic neoplasms, and are expected to simplify the existing multi-step diagnosis in liver imaging.

Numerous magneto-pharmaceuticals have been studied as potential tissue-specific MR contrast agents. A wide variety of vector and carrier molecules, including antibodies, peptides, proteins, polysaccharides, liposomes, and cells, have been developed to deliver magnetic labels to specific sites. Macromolecular MR contrast agents (blood pool agents) will be beneficial for improving the quality of MR angiography, for quantitating capillary permeability, and for myocardial perfusion imaging. The permeability of macromolecular tracers may also provide tissue uptake information for both contrast and chemotherapeutic drugs. Dedicated blood pool agents will be available within the next few years. Contrast-enhanced lymphography after interstitial or intravenous injection will be another major step forward in diagnostic imaging. Ultra small SPIO (USPIO) particles have been evaluated in multicenter clinical trials for lymph node MR imaging, and the clinical impact is taken up for discussion. It is likely that USPIO and gadolinium chelates will augment the MRI of atherosclerotic plaques, a systemic inflammatory disease of the arterial wall. Thrombus-specific agents based on gadolinium-labeled peptides are on the doorstep. Gd-porphyrins also can be used as a dual probe for MRI contrast agents and as a radiation sensitizer for neutron capture therapy. This may facilitate tumor detection and treatment planning and potentially improve the safety and efficacy of radiation therapy. Expectations for these new tumor-, pathology-, and receptor-specific agents are high.

A series of recent studies indicate that MRI cell tracking has great potential for the evaluation and optimization of stem and progenitor cell therapy. MR tracking of magnetically labeled cells following transplantation or transfusion could determine the distribution of these cells and monitor therapeutic effect. Up to now, SPIO particles appear to be the contrast agent of choice to label stem cells, owing to their biocompatibility and strong effects on proton T2* relaxation. Cell-tracking research has been performed in disease models of the central nervous system and the infarcted myocardium. With its excellent spatial resolution and the ability to track labeled cells over prolonged periods of time, MRI cell tracking is likely to become an important technique.

Technical advances in MR imaging will further facilitate the exploitation of tissue-specific MR contrast agents. The past history, recent trends, and prospects of MR contrast agent development are outlined in this review.

114 (114)　日獨医報　第50巻 第1号 114–132 (2005)

- 10年後には、USPIOやblood pool agentなど新しい造影剤をいくつか手にしている。
- さらに数年後には、組織特異性MR造影剤が日常的に使用されている。
- ただし、核医学に取って代わるものは数少なく、細胞外液性Gd造影剤が汎用される。

MRI造影剤開発の現状（表1）

A：発売中　B：治験終了　C:治験中

D:研究段階　E：研究未施行

1*：承認申請後中止
2*：開発中止

標的	薬剤	開発動向 国内	開発動向 海外
細胞外液	Gd-DTPA (Magnevist)	A	A
	Gd-DOTA (MAGNESCOPE)	A	A
	Gd-DTPA-BMA (Omniscan)	A	A
	Gd-HP-DO3A (ProHance)	A	A
	Gadoversetamide(OptiMARK)	C*1	A
	Gadobutrol (Gadovist)	B*2	A
肝網内系	Ferumoxides (Feridex, Endorem)	A	A
	Ferucarbotran (Resovist Inj.)	A	A
肝細胞	Gd-BOPTA (MultiHance)	B*1	A
	Gd-EOB-DTPA (Primovist)	B	A
	Gd-DTPA-DeA	C*2	E
	MnDPDP (mangafodipir)	E	A
	AG-USPIO	E	D
	MION-ASF	E	D
血液プール	MS-325 (Gadofosveset)	D	C
	B22956/1	E	C
	Gadomer-17	D	C
	P-792 (Vistarem)	E	D
	Ferumoxtran-10 (Combidex, Sinerem)	E	B
	NC 100150 (Clariscan)	E	B
	SH U 555C	E	D
	VSOP	E	D
Plaque	Gadofluorines	E	D
	Ferumoxtran-10 (Combidex, Sinerem)	E	B
リンパ節	Ferumoxtran-10 (Combidex, Sinerem)	E	B
	Gadofluorines	E	D
	Gd-DTPA-PGM	E	D
	Gd-carrying liposome	E	D
腫瘍	Gd-porphyrins	D	D
	MION-MoAb	E	D
	Gd-DTPA-9.2.27	E	D
膵	MnDPDP	E	A
	MION-CCK	E	D
心筋	MnDPDP	E	A
	MION-antimyosin	E	D
炎症	Ferumoxtran-10 (Combidex, Sinerem)	E	B
	MION-IgG		
細胞追跡	Ferumoxides (Feridex)	D	D
	Ferucarbotran (Resovist)	D	D
その他	Glucose感応薬	D	D
	pH感応薬	D	D
	遺伝子発現	D	D
消化管	Ferric ammonium citrate(FerriSeltz)	A	A
	MnCl2 (LumenHance)	E	C
	OMP	C*2	B

国内発売中

2005年　　7製剤

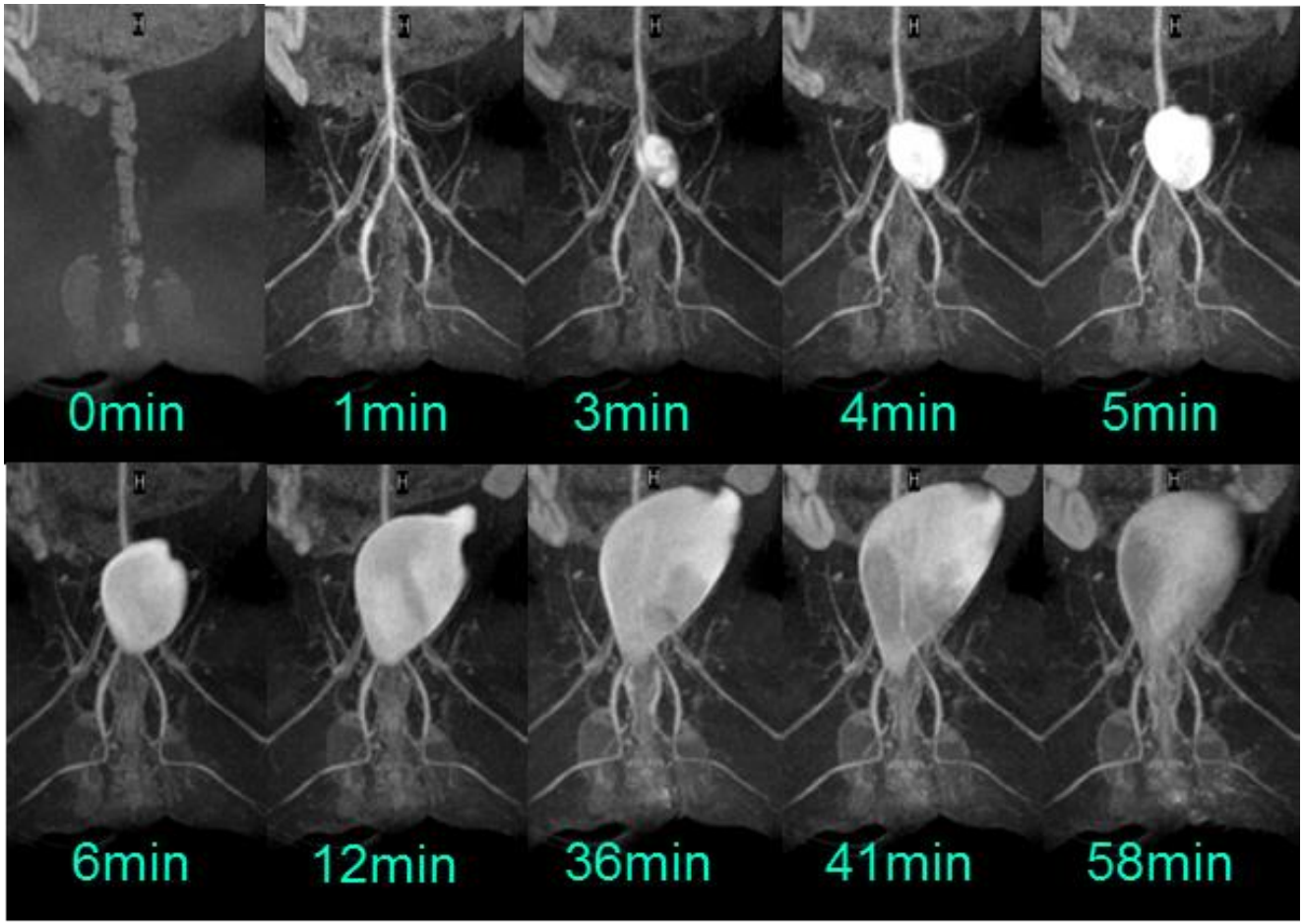
↓

2015年　　〇〇製剤

2006. Bothdel
2008. Gd-EOB-DTPA（Primovist）

MRI造影剤開発の動向　血液プール製剤　MS-325

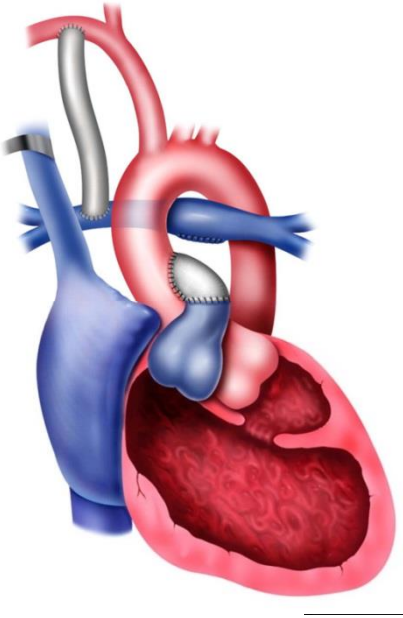
高空間分解能　vs SNR･CNR

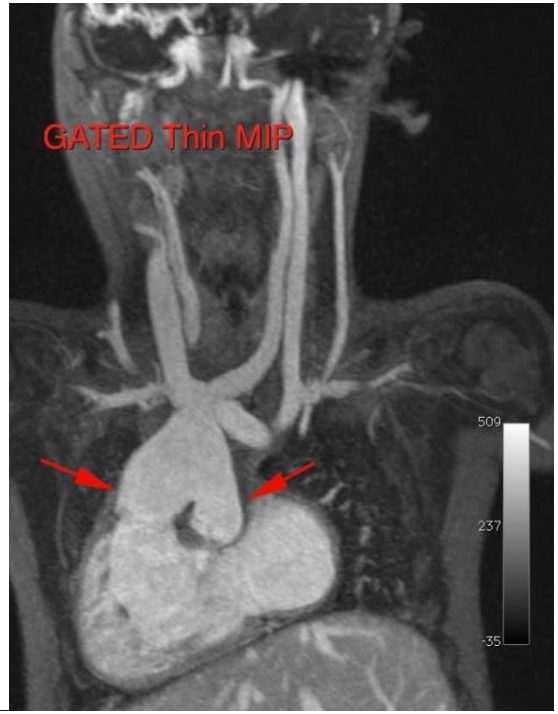


Yamashita T et al: Diffusion magnetic resonance imaging with gadofosveset trisodium as a negative contrast agent for lymph node metastases assessment. Jpn J Radiol. 2011.29.25-32.

MRI造影剤開発の動向　血液プール製剤　MS-325

高空間分解能　vs SNR･CNR





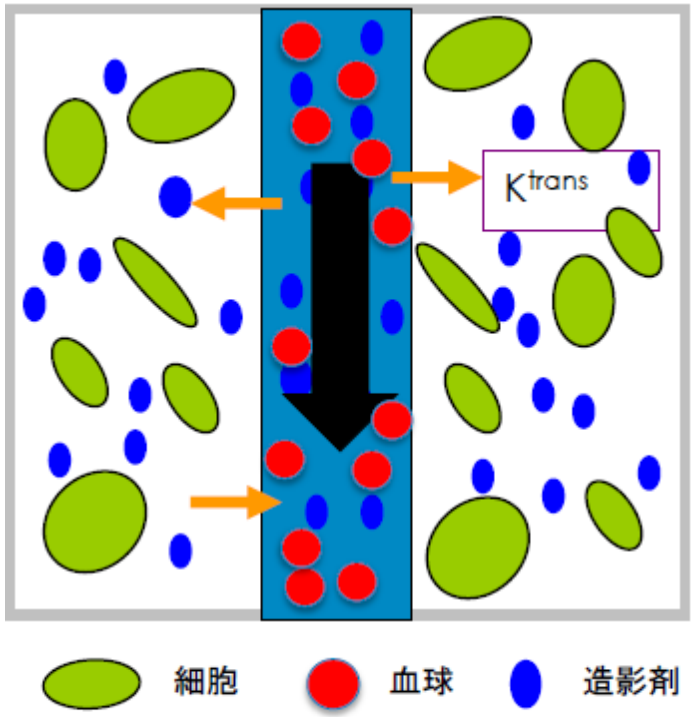
Adaptive Steady State Triggering adds confidence to the Thoracic ECG-Gated Contrast Enhanced MR Angiography.
Yutaka Natsuaki.
Proc. Intl. Soc. Mag. Reson. Med. 22 (2014) 0660.

A Multicenter MRI Protocol for the Evaluation and Quantification of Deep Vein Thrombosis.
Venkatesh Mani.
Proc. Intl. Soc. Mag. Reson. Med. 22 (2014) 3863

DCE-MRI permeability

信号強度を造影剤濃度に変換し薬物動態解析する手法
コンパートメントモデル解析が用いられる。

Tofts PS et al. 1991. Tofts and Kermode model
Brix G et al. 1991. Brix model
Tofts PS et al. 1999. Standard model



$$\frac{dC_t}{dt} = K^{trans}\,(C_p - C_t / V_e) = K^{trans}\,C_p - K_{ep}\,C_t$$

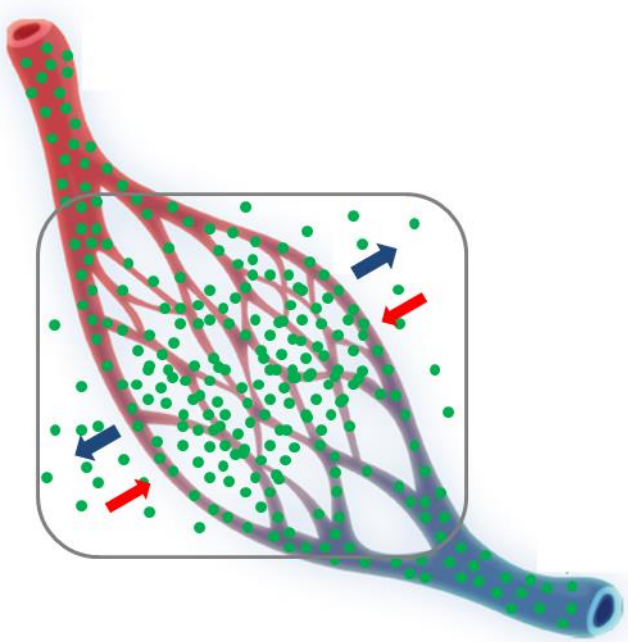
C_t	組織中の造影剤濃度
C_p	血漿中の造影剤濃度
V_e	血管外細胞外腔(ESS)の占める割合
V_p	血漿の占める割合
V_i	細胞内腔の占める割合
K^{trans}	造影剤の血漿からESSへの移行速度定数
K_{ep}	造影剤のESSから血漿への移行速度定数
	($K_{ep} = K^{trans} / V_e$)

DCE-MRI permeability

信号強度を造影剤濃度に変換し薬物動態解析する手法
コンパートメントモデル解析が用いられる。

動脈

毛細血管/組織

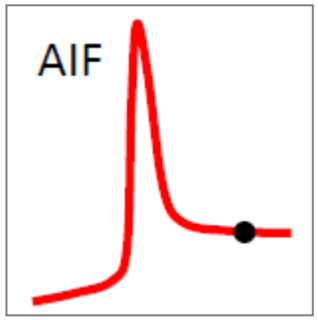


静脈

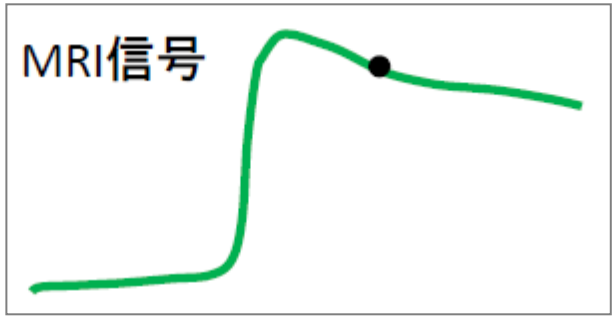
毛細血管レベルの現象を予測

$$\frac{dC_t}{dt} = K^{trans}\,(C_p - C_t / V_e) = K^{trans}\,C_p - K_{ep}\,C_t$$

INPUT



OUTPUT



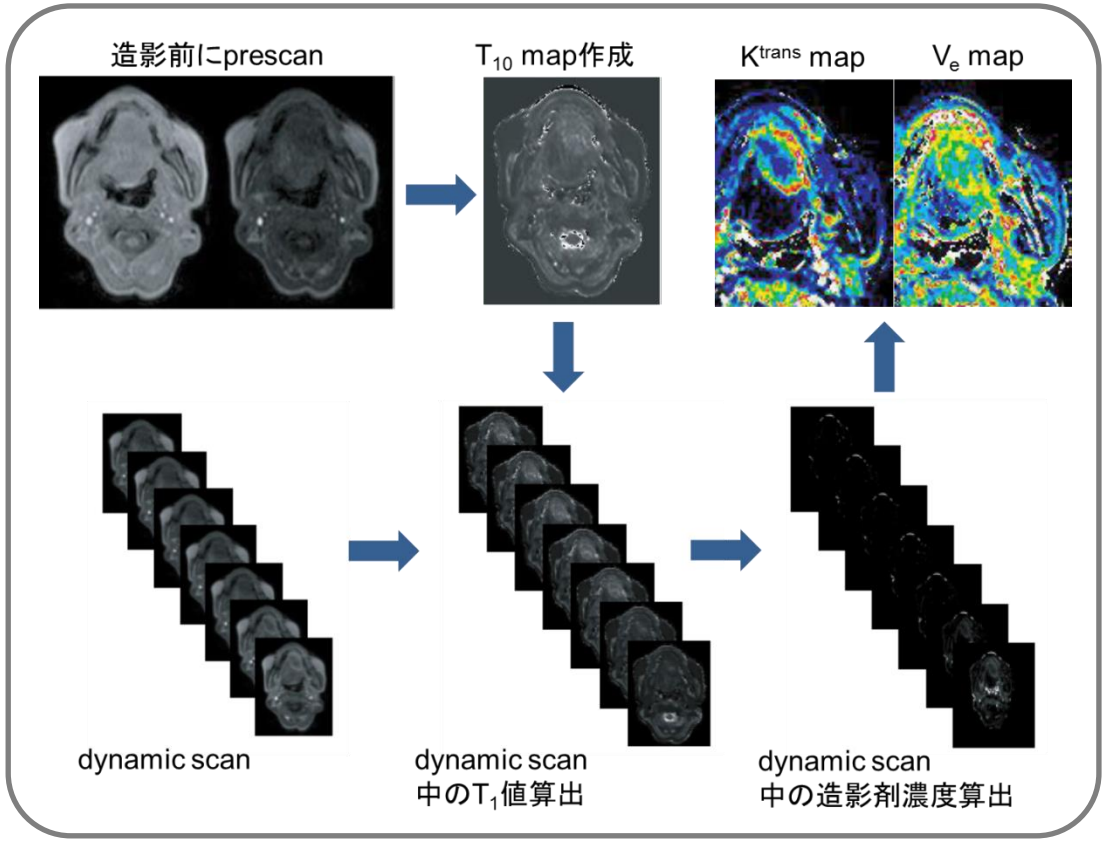
MRI信号S(t) → 造影剤濃度C_t(t)へ

DCE-MRI permeability

造影前とdynamic中のT_1値を算出できれば濃度算出は可能

$$1 / T_1 = 1 / T_{10} + r1\ C$$

T_1 :T_1値　T_{10}:造影前のT_1値　r1:縦緩和能　C:造影剤濃度



*応用自在　p20.筑井先生　より引用

Dual FA法

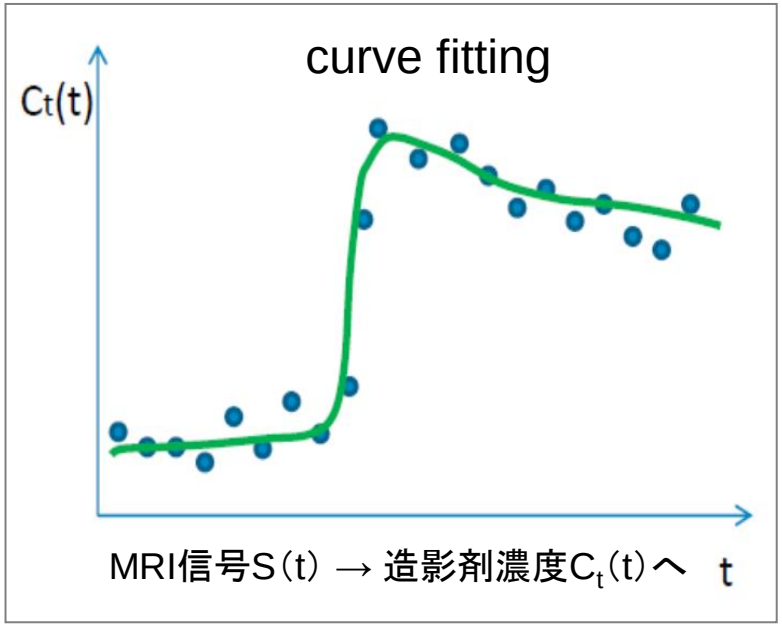
B1の影響を受けやすい

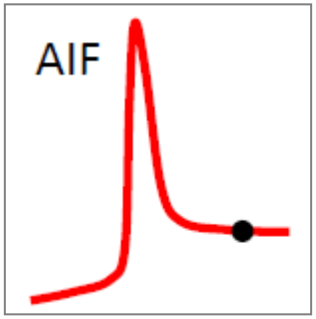
・Multi transmit
・B1map

DCE-MRI permeability

微分方程式を解いて

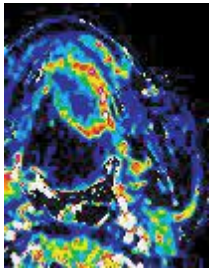
$$C_t(t) = K^{trans} \int_0^t C_p(t')\exp\left\{-\frac{K^{trans}(t-t')}{V_e}\right\} dt' + V_p C_p(t)$$



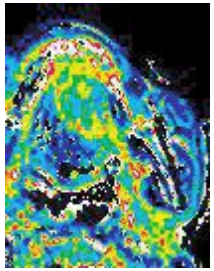


最適値を求める

K^{trans}



V_e



DCE-MRI permeability

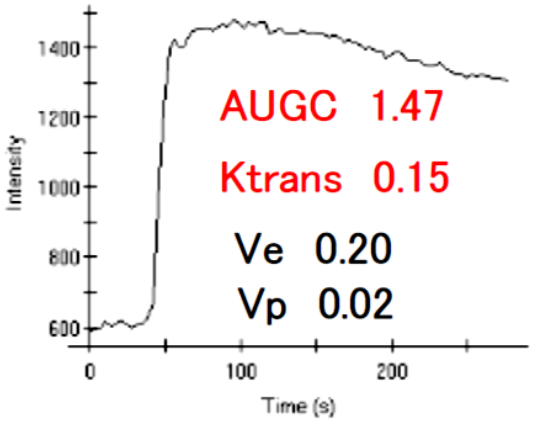
Cervical cancer : DCE MR and clinical outcome

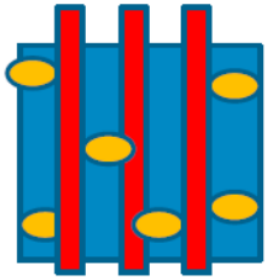
Author	n	Parameter	Outcome
Hawighorst, 1998	57	Low K_{ep}	↓ Survival
Yamashita, 2000	36	High "permeability"	"Poor response"
Mayr, 2000	16	$RSI_{10\%}$<2.5	↓ Local control
Loncaster, 2002	50	Low A_{Brix}	↓ Survival
Zahra, 2009	13	High K^{trans} or K_{ep}	"Better regression"
Semple, 2009	8	K^{trans}	"Clinical response"
Donaladson, 2010	50	EF25s>28%	↓ Survival
Andersen, 2011	81	Low $RSI_{10\%}$, low AUC	↓ Local control

Michael M. MR Functional Imaging to Guide Radiotherapy: challenges and Opportunities.

DCE-MRI permeability

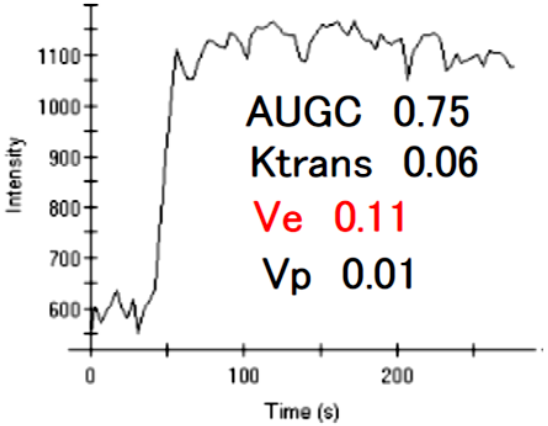
扁平上皮癌

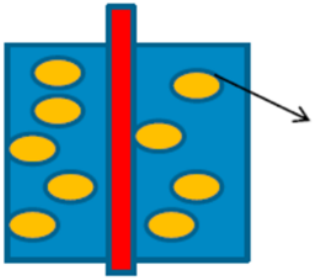




flowが高い
もしくは血管壁の破綻

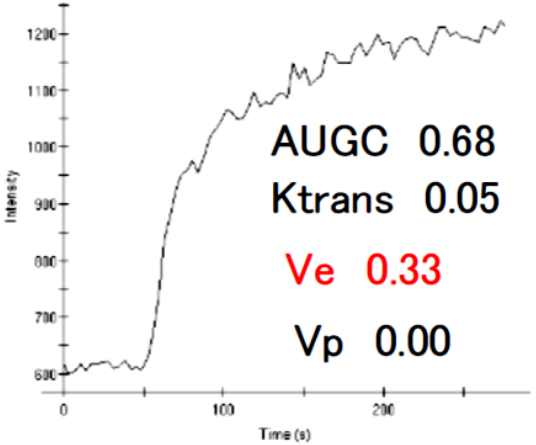
悪性リンパ腫

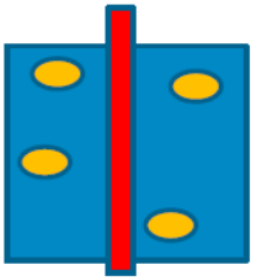




細胞密度が高い

多形性腺腫





細胞密度が低い

DCE-MRI permeability

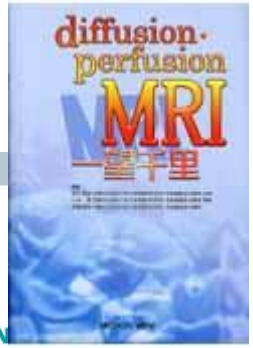
T1強調DCEイメージングの
コンセプト：モデリング、撮像、解析

ダイナミック造影
T1強調イメージングをはじめとする
直腸内コイルを用いない前立腺
1.5テスラ機能的MR

Multi-Imagingの検査プロトコル
による初期の臨床経験

・血管新生阻害療法/抗血管内皮増殖
因子（VEGF）療法の評価

・抗がん剤開発への応用



Web 入手可能です。

最後に

大切なことは、昔から変わらない。

- 造影剤とシーケンスを把握する。
- 造影前後は同じものを撮る。（脂肪抑制）
- 造影検査の役割を理解する。
- 調べてみる。変えてみる。

皆様のご参考になれば幸いです。ご清聴ありがとうございました。

謝辞　DCE-MRI permeabilityに関して、ご意見を頂きました。
ありがとうございました。
小原　真　様（PHILIPS ）　打越　将人　様（SIEMENS）