Seminaire Virtuel

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez **30 Avril 2020**

Affiliation:
Centre de Recherche du CHUM

Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine

Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez 30 Avril 2020

Divulgation :
Siemens is funding Dr Cyril Tous for this research project

Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

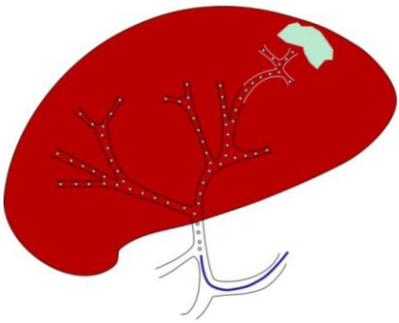
Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez 30 Avril 2020

Hepatocellular carcinoma represents the 5th most common cancer in men and the 7th in women with 2500 new cases in Canada in 2017. Patients with untreated liver cancer have a very poor prognosis with a 5-year survival rate <5%.

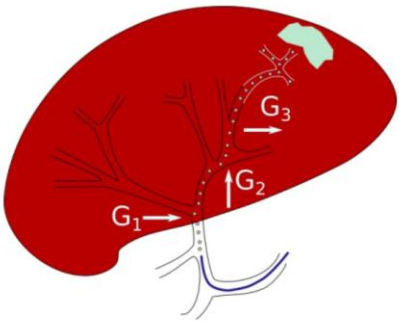
Intra-arterial hepatic chemotherapy (classic embolization) uses a catheter to release anti-tumor drugs agents in the main hepatic artery but suffers from poor selectivity (a).
We propose to encapsulate the therapeutic agents with superparamagnetic particles (180um) and use in-house injector to form aggregates that provide magnetic dipole-dipole interaction with the MRI gradients (b). Such bolus (~1mm) can be steered to the tumor (c). Once removed from the magnetic field, the bolus disaggregates in the vessels feeding the tumor (d).

MRN concept



Classic chemoembolization:
The entire liver is affected

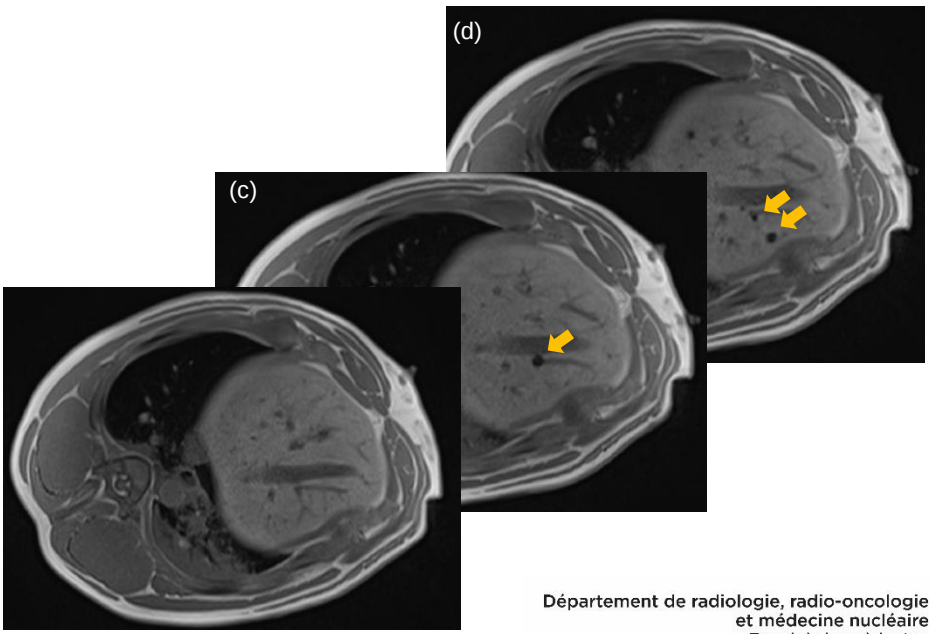
(a)



Chemoembolization guided
by MRI gradients:
Only the tumor area is affected

(b)

MRN in in-vivo pig



Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez

1. Making micro drug eluting beads into aggregates
2. Magnetic resonance navigation
3. Taking advantage of the gravity
4. Taking advantage of the MRI gradients
5. Taking advantage of the blood flow
6. Visualization of embolization

Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

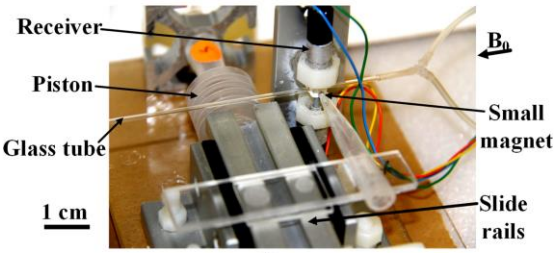
Tous, Li, Lessard, Soulez

1 2 3 4 5 6

1) Making micro drug eluting beads into aggregates

(a)

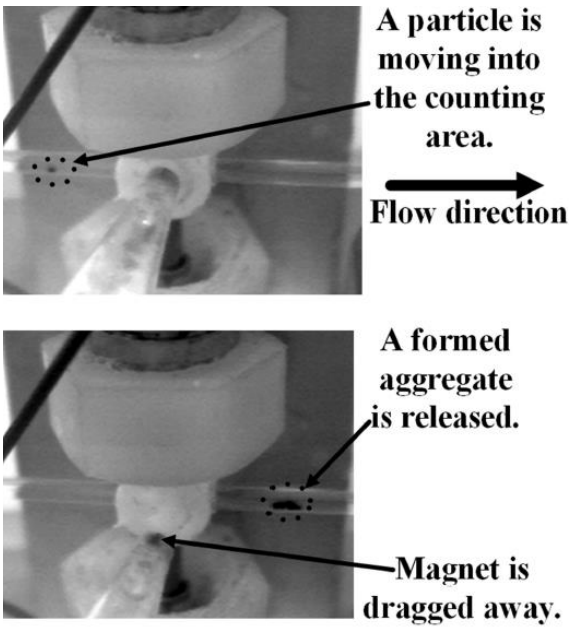
Biodegradable therapeutic magnetic microcarriers (180um) are injected with a pump to an actuator (a).



(b)

The magnetic trap of the actuator controls the number of beads to form an aggregate until a resistance threshold value is reached (b).

A signal is sent to displace the small magnet trap and release the aggregate
(25 beads, 1mm)



(c)

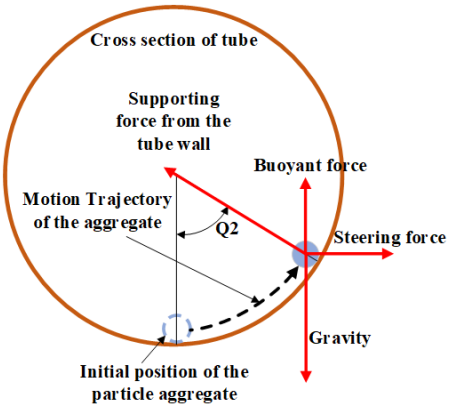
Département de radiologie, radio-oncologie et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez

1 → 2 → 3 → 4 → 5 → 6

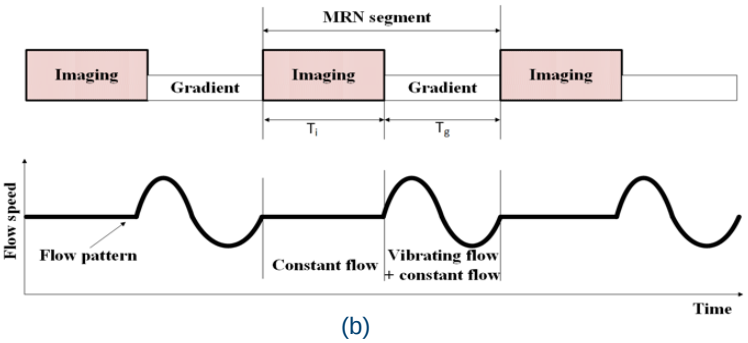
2) Magnetic resonance navigation of the aggregate



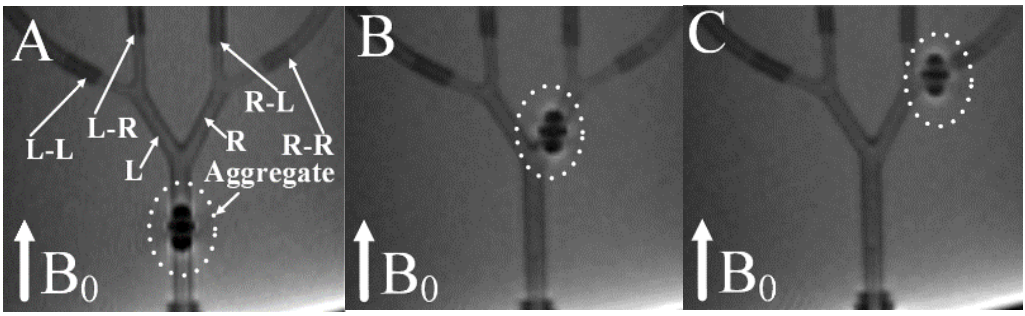
(a)

Due to their density the aggregates tend to accumulate at the bottom of the vessel wall. A steering force is applied to the aggregate by the MRI gradients to target the branch of the nodule (a).

By alternating imaging and steering (b), in-vitro experiments show that we can reach 100% selectivity in one branch phantom and 80% for the second branch (c).



(b)



(c)

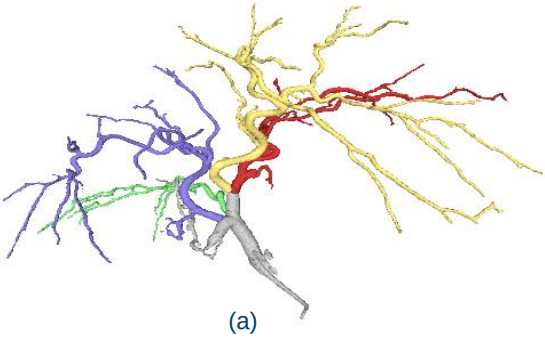
Département de radiologie, radio-oncologie et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

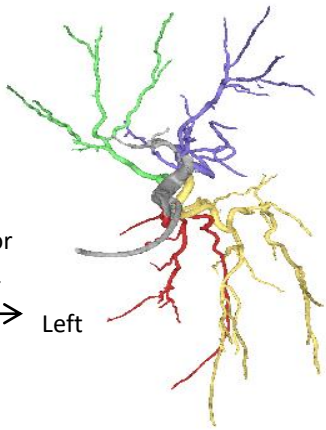
Tous, Li, Lessard, Soulez

1 → 2 → 3 → 4 → 5 → 6

3) Taking advantage of the gravity



(a)

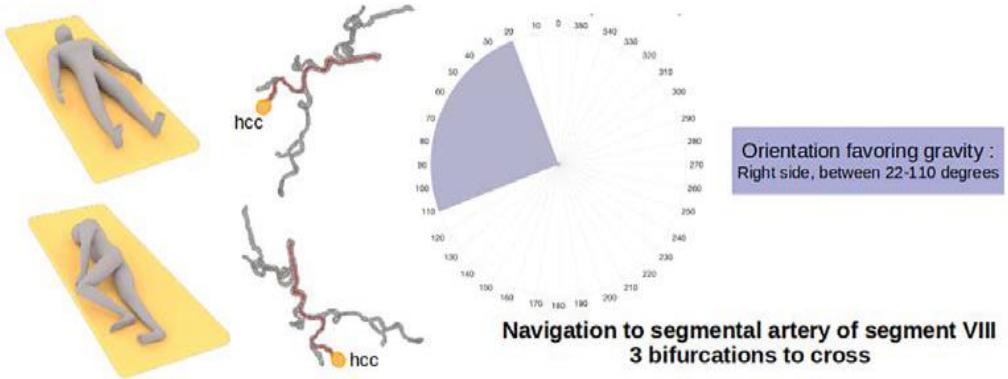


(b)

The gravitational force is 20×10^{-7} N while one MRI gradient is 7.2×10^{-7} N.

Preliminary results from the segmentation of angiography X-ray images are used to determine the optimal position of the patient that will favor gravity toward the tumor's location (a). In our in-vivo experiment on pigs, we titled the position by 29° (b).

In an atlas of 19 patients with a total of 32 nodules (c), we found that the segment feeding tumors can be reached within two bifurcations in the left and three bifurcations in the right lobe. All the nodules could be reached with MRN combined with the gravity.



(c)

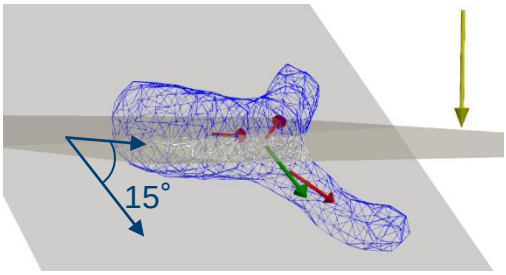
Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez

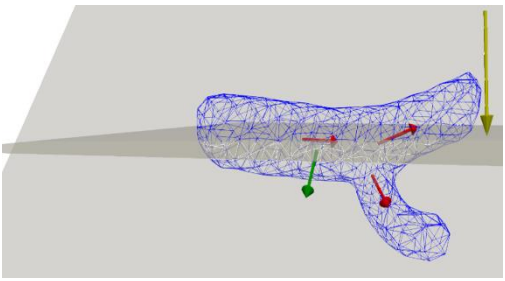
1 2 3 4 5 6

4) Taking advantage of the MRI gradients



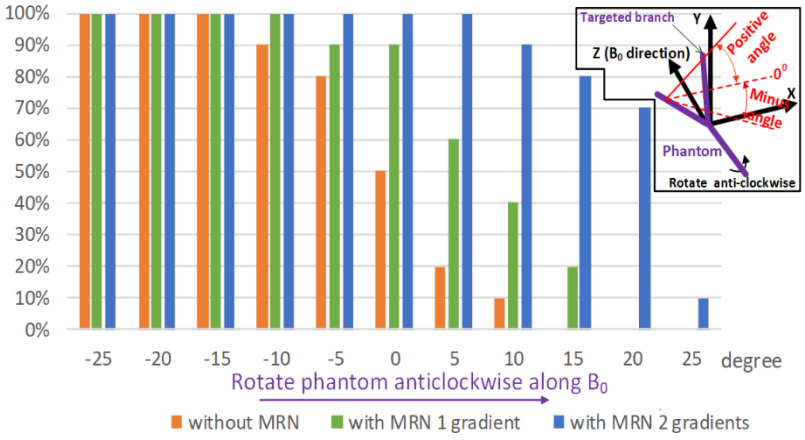
(a)

Once in the appropriate position according to the gravity (yellow arrow), MRN is used to select the branch. The main direction of the branches is depicted in red arrows. One MRN gradient is applied perpendicular to the main branch (a, b).



(b)

By titling a one bifurcation phantom, and simulating in vivo flow condition, we found that the combination of two activated gradients provide sufficient steering against the gravity up to 20 degree (c).



(c)

Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

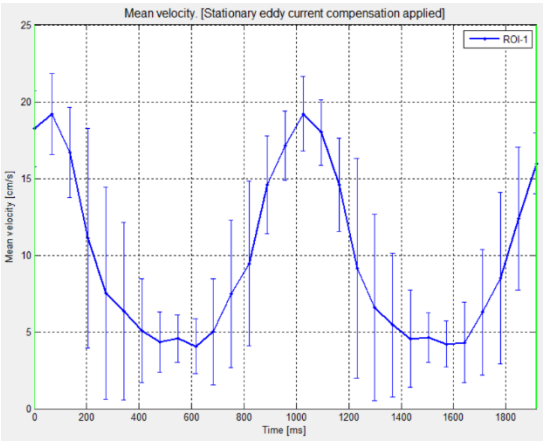
Tous, Li, Lessard, Soulez

1 → 2 → 3 → 4 → **5** → 6

5) Taking advantage of the blood flow

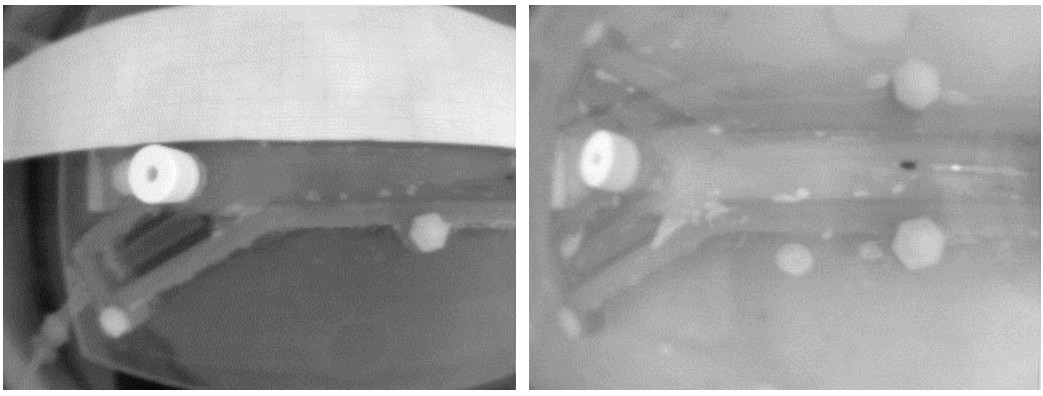
Flow was controlled by a partial inflation of a balloon catheter in the proper hepatic artery to maintain a peripheral flow while injecting particles at 0.25ml/s. Bypass pulsatile flow minimizes the friction force and allows the aggregate to be steered.

The flow velocity was estimated using MR 2D cine phase contrast. The velocity dropped from 35 cm/s to 15 cm/s at systole and from 10 cm/s to 5 cm/s at diastole, maintaining a pulsatile flow.



In vivo flow condition was reproduced with a cardiac pump (a) and success rate was evaluated in a PVA phantom with similar friction force as vessels (b). The drag force was estimated from the aggregate and flow velocity.

(a)



(b)

Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal

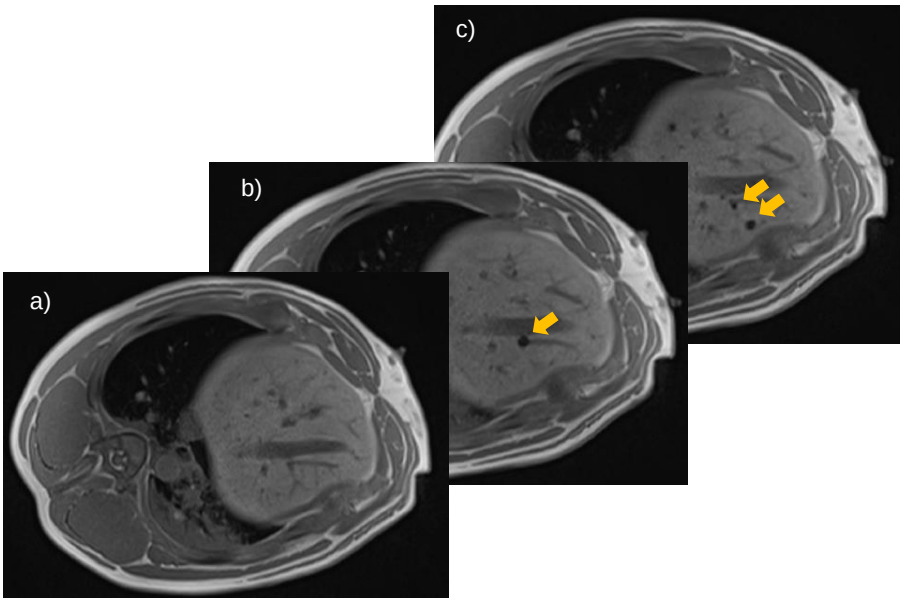
Magnetic resonance navigation system for supra-selective embolization of the liver: *in vivo* demonstration.

Tous, Li, Lessard, Soulez

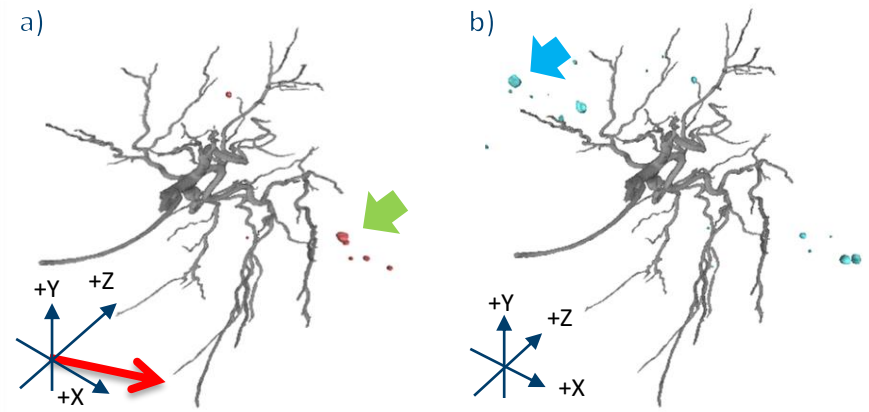
1 → 2 → 3 → 4 → 5 → **6**

6) Visualization of embolization

MRI image (T1 VIBE) acquired before (a) and after (c) injection of an aggregate showing a proximal location of the bolus identified by their artifacts (orange arrow). The swine was removed from the main magnetic field $\overrightarrow{B0}$ and replaced in $\overrightarrow{B0}$ for imaging (c). Aggregate broke and particles become peripheral (orange arrows) reaching the arterioles feeding the tumor.



Accumulation of aggregates (green arrow) in the left medial lobe with MRN according to the steering direction (X,-Y,Z) (red arrow). 2. Accumulation of aggregates in the right lobe without MRN (blue arrow).



Département de radiologie, radio-oncologie
et médecine nucléaire
Faculté de médecine
Université de Montréal