Use of magnetic resonance elastography for monitoring of hepatic tumor radioembolization

Philippe Garteiser[1], Arnaud Dieudonne[1,2], Rachida Lebtahi[2], Mohamed Abdel-Rehim[3], Valerie Vilgrain[3], Ralph Sinkus[1], and Bernard E Van Beers[1,3]
[1]CRB3 U773 Université Paris Diderot, Sorbonne Paris Cite, INSERM, Paris, 75018, France, [2]Service of Nuclear Medicine, Hopital Beaujon, Clichy, France, [3]Service of Radiology, Hopital Beaujon, Clichy, France

Objective: Evaluate the feasibility of using magnetic resonance elastography (MRE) to aid in the localization of radioembolization yttrium microspheres by exploiting the effect of the microspheres on material mechanical properties.

Rationale : Hepatic tumor embolization with solid glass microspheres containing yttrium (^{90}Y, half-life 2.7 days) is a new treatment for non-resectable hepatocellular carcinomas. Bremsstrahlung imaging may be used to visualize the resulting distribution of the microspheres, but this technique is not available at all centers (requiring a SPECT-CT), and provides suboptimal results in terms of spatial resolution and accuracy. The solid-like property of the beads may induce alterations in the mechanical properties. In the present work, the effect of the presence of radioembolization ^{90}Y microspheres on the mechanical properties of a solid matrix was tested. Proof of principle data were acquired in a patient with a hepatocellular carcinoma before and after embolization. ^{90}Y microspheres localization using magnetic resonance elastography was compared to the reference technique of bremsstrahlung imaging.

Protocol: Magnetic resonance elastography (MRE) was performed on a clinical 1.5 T system with an isotropic spatial resolution of 4mm (patient) or 2mm (phantom) and a periodic motion-sensitized sequence with an electro-mechanically generated acoustic wave frequency of 50 Hz (gradient echo, patient) or 90 Hz (spin echo, phantom). The effect of the ^{90}Y microspheres on the material properties was investigated on a 10g/l agarose gel phantom (yielding an elasticity of 12.4 kPa), in which we placed an inclusion containing spent ^{90}Y microspheres (average diameter of 25 µm) at a sphere concentration of 200 spheres/mm^3[1]. The suspension was prepared assuming a cubic packing of spheres (volume ratio of π/6). A patient whose hepatocellular carcinoma was treated with ^{90}Y radioembolization microspheres under standard conditions (TheraSphere, MDS Nordion, Canada) underwent MRE of the liver before and one day after embolization. Bremsstrahlung imaging was carried out immediately after radioembolization using described methods[2].

Results: The elasticity of the inclusion containing spent ^{90}Y microspheres was of 19.6 ± 2.1 kPa and that of the agarose matrix 12.3 ± 4.1 kPa (fig. 1). The patient presented a very large and heterogeneous tumor, occupying most of the right liver lobe. Zonal processing of the liver tumor revealed several distinct responses (table). The major part of the tumor had decrased values of elasticity and viscosity (green ROI), whereas some smaller regions (« hotspots ») displayed increased stiffness (red and blue ROIs). At bremsstrahlung imaging, ^{90}Y microspheres were distributed throughout the tumor (dose of 28 Gy at the time of the MRE). The blue and red hotspot regions identified using MRE corresponded to a high signal (> 50 % relative to green ROI) in bremsstrahlung imaging.

Discussion: The glass material used for ^{90}Y microspheres is known to have a much higher stiffness than liver tissue, and as a suspension of small objects, may alter acoustical wavelengths via diffractions. In vitro, the spheres stiffened their environment, yet decreased elasticity values were observed in the tumor in locations with high doses of radiations. The 24 hours between embolization and MR examination were too short for significant radiation-induced tissue damage, and hence direct radiation effects may not have changed the mechanical properties. The observed decrease in mechanical properties may tentatively be attributed to a lower blood perfusion or to hypoxic necrosis, both potential consequences of a diffuse, weak embolization caused by the microspheres, independently from their radiotherapeutic effect. The presence of focal areas with increased elasticity values may be explained by an inhomogeneous distribution of the embolizing material. This preliminary work will need validation on a greater cohort of patients (N = 10), combined with an assessment of microperfusion at MR.

		before embolization		24 hrs post embolization	
		mean	st. dev	mean	st. dev
green area	Elasticity (kPa)	2.32	0.61	2.00	0.62
	Viscosity (kPa)	0.74	0.33	0.86	0.43
blue area	Elasticity (kPa)	2.31	0.50	3.05	0.61
	Viscosity (kPa)	1.14	0.40	1.08	0.47
red area	Elasticity (kPa)	2.88	0.68	1.77	0.49
	Viscosity (kPa)	0.91	0.41	0.41	0.18

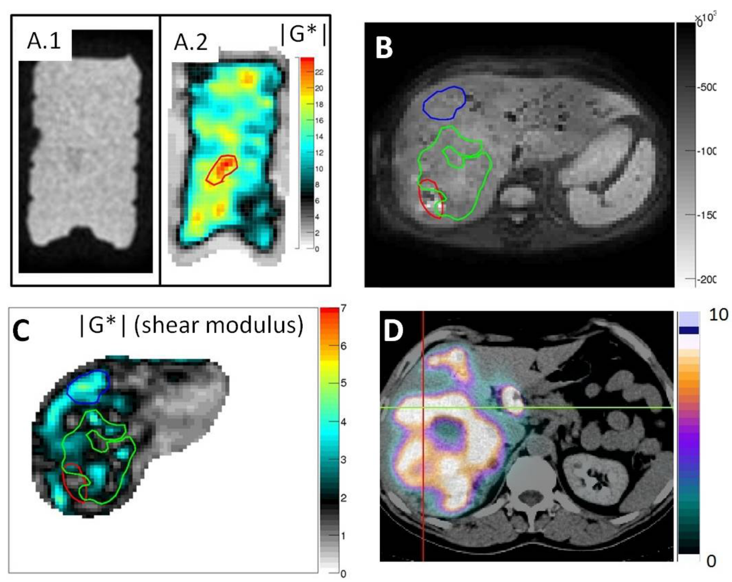

Figure: A: Yttrium beads agarose gel phantom. A.1: MR magnitude image. A.2: shear modulus image (square sum of elasticity and viscosity; color scale in kPa). The inclusion is seen as an area with increased elasticity. B: magnitude MRE image 24 hours post embolization. The regions of interest referred to in the text are depicted. C: shear modulus map 24 hours post embolization (color scale in kPa). D: bremsstrahlung image immediately after radioembolization. Coregistration is observed between areas of high bremsstrahlung radiation activity and the mechanical parametric map.

[1] Campbell A M, Bailey I H, Burton M A, Analysis of the distribution of intra-arterial microspheres in human liver following hepatic yttrium-90 microsphere therapy, Phys. Med. Biol. (2000) 45:1023 ; [2] Mansberg R, Sorensen N, Mansberg V, Van der Wall H, Yttrium 90 Bremsstrahlung SPECT/CT scan demonstrating areas of tracer/tumour uptake, Eur J Nucl Med Mol Imaging (2007) 34:1887