

## The development of bone cement for the interventional MRI.

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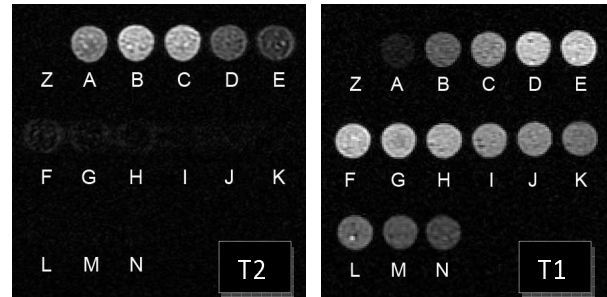
**Introduction:** Since its discovery by Otto Röhm back in 1902, multiple applications of PMMA bone cement were established in clinical treatment (1). While the early use in dentistry and orthopedic implant fixation became indispensable over the last six decades (2, 3), vertebroplasty and cancer surgery increased the range of application (4, 5, 6) recently. As bone cement has no signal in the MRI, it cannot be directly visualized and it is therefore difficult to detect leakage during and after an intervention (7, 8). In order to establish vertebroplasty and cancer surgery in the open MRI, visible cement becomes necessary.

**Materials & Methods:** Ordinary PMMA-Cement (BonOS, AAP, Germany) consists of a powdery (PMMA) and a liquid part (MMA) which set after being compounded. Several established contrast agents, such as Gadolinium-DOTA (Dotarem, Lab. Guerbet, France), Gadolinium-BOPTA (Multihance, Bracco, Italy/USA) and Mangafodipir (Teslascan, GE Healthcare, UK), as well as other substances such as manganese or oil, were added. The agents were applied in dilution series to obtain the ideal concentration in their vehicle (Table 1). The vehicle was 0,9 % saline solution, alcohol or oil. Most of the substances were recombined, and used as contrast agents or vehicles. It was necessary to develop a mixing technique because the liquid part of PMMA-Cement (MMA) is hydrophobic whereas most of the agents are not. Therefore amphiphilic substances, which are hydrophilic and lipophilic (such as alcohol and Gd-BOPTA) were brought in. However a steady mixing also guarantees appropriate setting of the cement. The modified PMMA series were scanned in 10 ml injections on a 1,5 Tesla Gyro Scan MRI System (Philips Medical Systems, Best, The Netherlands) (Fig.1&2). A control group was measured with the contrast agents and their vehicle only, in the same dilution concentrations.

**[(Agent+ 5ml 0,9% NaCl)+MMA]+PMMA= Cement A-N**

Vertebral columns and proximal tibiae were drilled and filled with several cements. T1 GRE (TR: 6,9ms, TE: 1,9ms,  $\alpha$ : 60°, slice thickness: 5mm), bSSFP (TR: 5,4ms, TE: 2,7ms,  $\alpha$ : 65°, slice: 5mm) and T1W FSE (TR: 848,1ms, TE: 11,0ms,  $\alpha$ : 90°, slice: 4mm) sequences were scanned in order to have fast imaging for intervention (Fig. 3,4&6) and T2W FSE

(TR: 2500,0ms, TE: 200,0ms,  $\alpha$ : 90°, slice: 4mm) for best diagnostics in spine and bone (Fig. 5). All scans were performed in a head coil.



**Fig.1.2.** Dilution series of cement with contrast agent in T2&T1 W FSE Z= conventional PMMA cement. A-N see Table 1 (below)

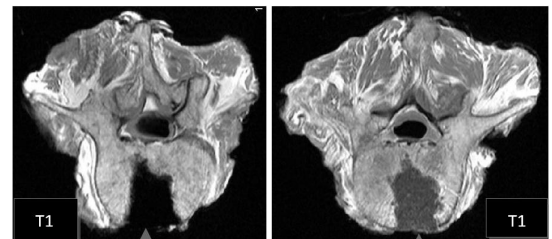
**Table 1**

Cement	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Contrast Agent ( $\mu$ l)	0	2,5	5	15	25	50	75	100	125	150	200	250	300	350
NaCl 0,9% (ml)	5	5	5	5	5	5	5	5	5	5	5	5	5	5
MMA ( ml)	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Cement powder (g)	12	12	12	12	12	12	12	12	12	12	12	12	12	12

**Results:** The cement produced a clear positive contrast in all sequences. Although the control group (contrast agent + vehicle) had a better signal than the cement, their results were

comparable. Mixing the liquid parts first and adding them later to the cement, seems advantageous. Amphiphilic substances, Gd-BOPTA and alcohol were not necessary. The signal correlated with the contrast agent concentration to its peak in order to drop afterwards until extinction. This peak depended on the Sequence (T1- or T2-weighted). For Gd-DOTA the bSSFP sequence had the broadest sensitivity, while T1- and T2-weighted FSE series had their maximum at 3-20 $\mu$ l Gd-DOTA/ml 0,9 % saline solution respectively at 0,5-1  $\mu$ l/ml. The Scans in human cadaver bone showed the exact identification of the PMMA (Fig. 4-6).

**Conclusion:** PMMA bone cement can be prepared in order to give a positive contrast in the MRI. Biomechanical and toxicological tests need to prove its safe application in clinical use. This cement may improve safe intervention in the open MRI, and allow early coping of complications due to leaking.



**Fig. 3**

Conventional PMMA in a vertebral body, transversal, T1 W FSE

**Fig. 4**

Gd-DOTA/PMMA (100 $\mu$ l) in a vertebral body, transversal, T1W FSE

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**Fig. 5:** vertebral column, coronal, 3 vertebral bodies filled with cement. T2 W FSE

**Fig. 6:** vertebral column, saggital, two vertebral bodies filled with cement T1 GRE