A New Highly-Radiopaque Bone Cement with Built-in Iodine, and its Potential Utility in Vertebroplasty.

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Introduction. Vertebroplasty has become an accepted method to treat osteoporotic vertebral compression fractures. A recent scientific study has made clear that vertebroplasty leads to significant pain reduction (as compared to sham operation), both in the short term and in the long term [1].
From the perspective of biomaterials science, it seems clear that vertebroplasty cements, as currently provided by industry, are a point of weakness. The commercial cements are –essentially- adapts from the cements for knee- and hip arthroplasty. The major change is that additional contrast agent ($BaSO_4$ in almost all cases) is added to the cement. The high load of $BaSO_4$ affects the physical mechanical properties of the cement and the flow properties of the cement dough, and there are suspects about possible effects of $BaSO_4$ on bone resorption.
Here, we introduce a new cement in which high contrast is realized through incorporation of iodine in two ways: (i), iodine is covalently bound to a methacrylic copolymer [2], and (ii) the tetraiodocarborane compound I4C2B8H10 [3] is built into roughly 50 % of the microspheres in the powder portion of the cement. The tetraiodocarborane compound is an attractive contrast additive, since it has a high iodine content, exceptional stability, and the compound is essentially insoluble in aqueous media.

Methods. The new cement has been studied several techniques. New microspheres were characterized, (SEM, XPS, cytotoxicity). Handling characteristics were determined (setting times, max. temperature). The cements was characterized extensively (backscatter SEM, XPS, radiography, solid state NMR, mechanical testing (compression tests), biocompatibility in vitro (Live-Dead, MTT). Moreover, the cement has been used in a preliminary experiment in which the material was injected into a human cadaveric vertebral corpus.

Results. Synthesis of microspheres containing both iodine that is covalently bound to one of the constituting copolymers, and iodine within tetraiodocarborane, was successful. Also, cement preparation was successfull, with handling parameters that are very similar to those of commercial vertebroplasty cements. Figure 1 shows backscatter scanning electron micrographs of the new

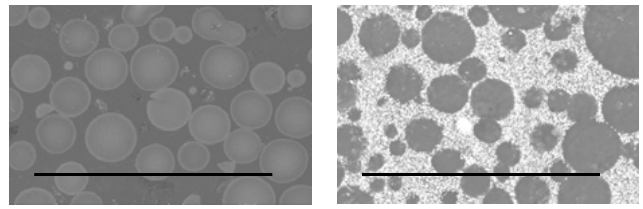

Figure 1. *Backscatter SEM micrographs of the new iodine-containing cement (left) and of a commercial vertebroplasty cement (right). Note that the contrastresides within the microspheres of the new cement, whereas the contrast particles (BaSO4) of the commercial cement are situated around the microspheres. Scale bar = 1000 micrometer (left and right).*

cement (left), and of a commercial counterpart cement that contains elevated concentration of $BaSO_4$ (right). Note that the new cements are radiopaque due to the presence of iodine *within* the constituting microspheres, whereas the commercial cement is radiopaque because of $BaSO_4$ that is embedded *around* the constituting microspheres.
Both XPS and solid state NMR provided compelling evidence that the tetraiodocarborane compound remained intact during the cement preparation. Furthermore, XPS revealed that the tetraiodocarborane is distributed evenly over the volume of the microspheres. Compression experiments pointed out that the new cement has the same compressive elastic modulus, as the commercial $BaSO_4$ containing counterpart. The Live-Dead assay showed that the material is not cytotoxic to osteoblast cells, and the MTT test showed absence of toxic susbstances in the material's aqueous extracts.

Conclusion. The combined experimental data point out that the new radiopaque cement, that owes its radiopacity to built-in iodine, has attractive properties for use in vertebroplasty. Further work into this direction is currently ongoing in our laboratories.

References.

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