Supporting Information for

Strategies for Increasing Relaxivity of Gold Nanoparticle Based MRI Contrast Agents

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S1: Determination of magnetic parameters of free vanadyl (VO^{2+}) and VO-DTPA@AuNPs

The principal values of *A* and *g* tensors for free vanadyl (VO^{2+}) and VO-DTPA@AuNPs were determined from simulating EPR spectra of frozen solutions (Figure S1). The 10% aqueous glycerol was used as a solvent for recording EPR spectra at 130 K. The values of *A* and *g* tensors are shown in Table S1 and were similar to those reported in the literature.[1]

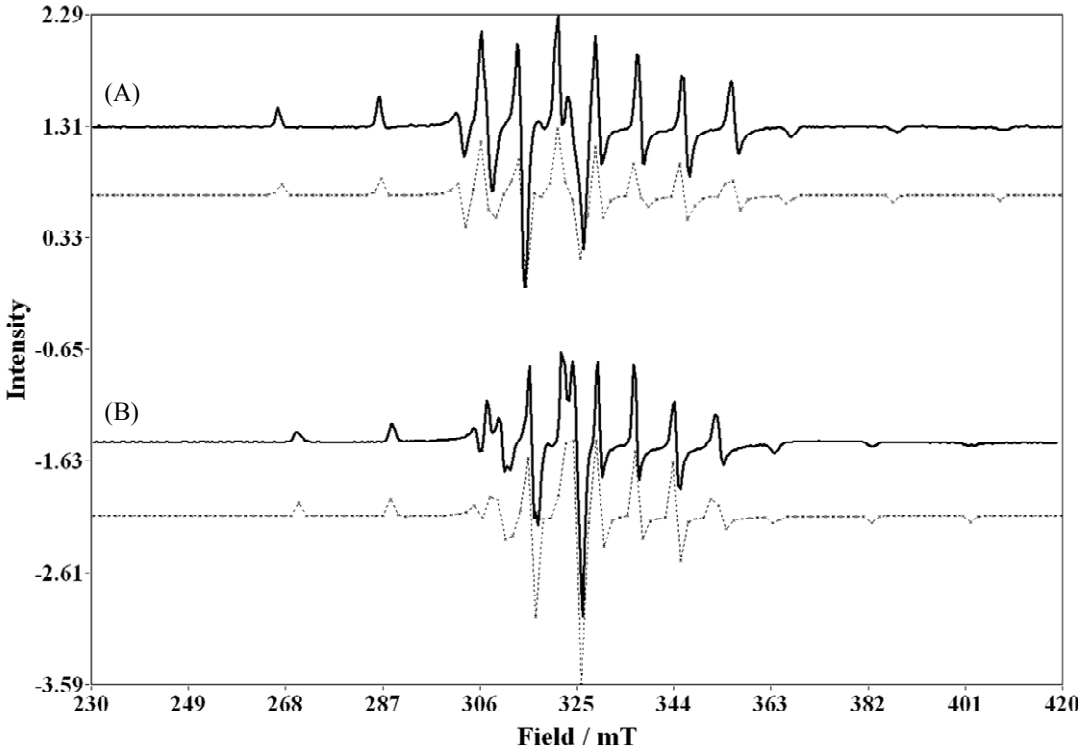

Figure S1: Experimental (solid lines) and simulated (dotted lines) EPR spectra of free vanadyl (A) and VO-DTPA@AuNPs (B) at 130 K.

Table S1: Magnetic parameters of free VO^{2+} and VO-DTPA@AuNPs

S. No.	Paramagnetic species	*A* / MHz			*g*		
		A_{xx}	A_{xy}	A_{zz}	g_{xx}	g_{xy}	g_{zz}
1	$VOSO_4$	207.3	210.4	543.9	1.9772	1.9708	1.9338
2	VO-DTPA@AuNPs	175.1	187.0	511.7	1.9755	1.9783	1.9412
3	VO-DTPA*	186.1	172.0	508.2	1.980	1.978	1.944

***Literature values**

S2: UV-Vis. spectra of grown gold nanoparticles

The UV-Vis spectra of large AuNPs (AuNPs-**II** & **III**) along with small AuNPs-**I** are shown in Figure S2.

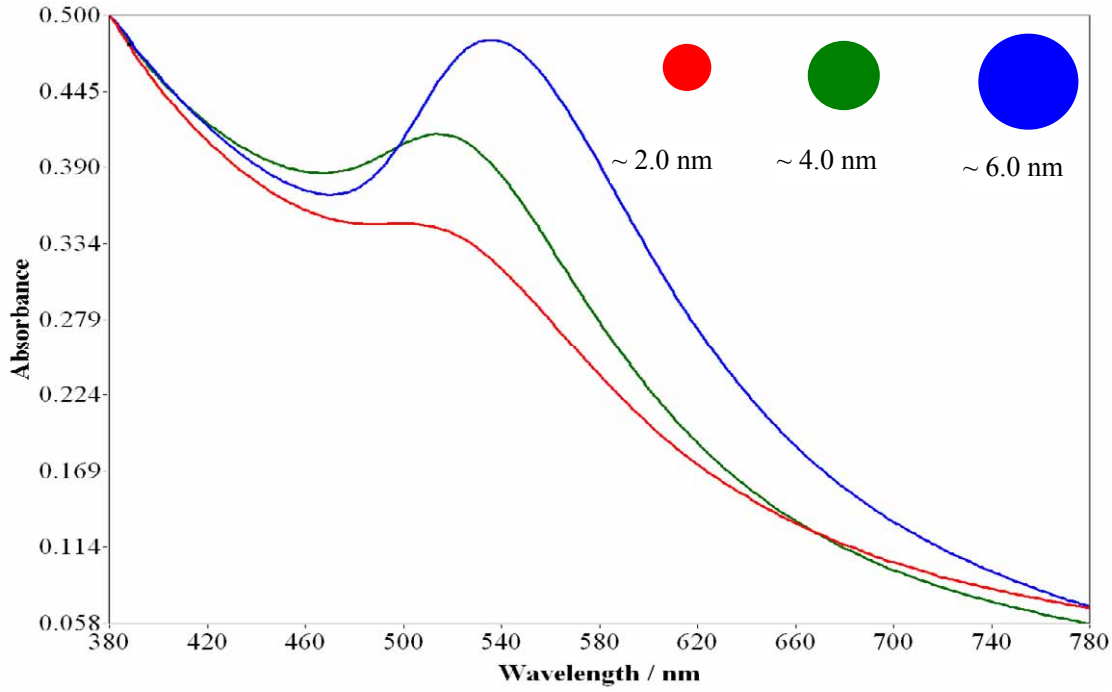

Figure S2: UV-Vis. spectra of small and large AuNPs.

S3: TGA analysis

The TGA analysis was carried out to estimate the organic contents in AuNPs. The TGA curves for AuNPs-**I** (~2.0 nm), **II** (~4.0 nm) and **III** (~6.0 nm) are shown below. The weight loss was found 42 %, 17 % and 8.0 % for AuNPs-**I**, **II** and **III,** respectively.

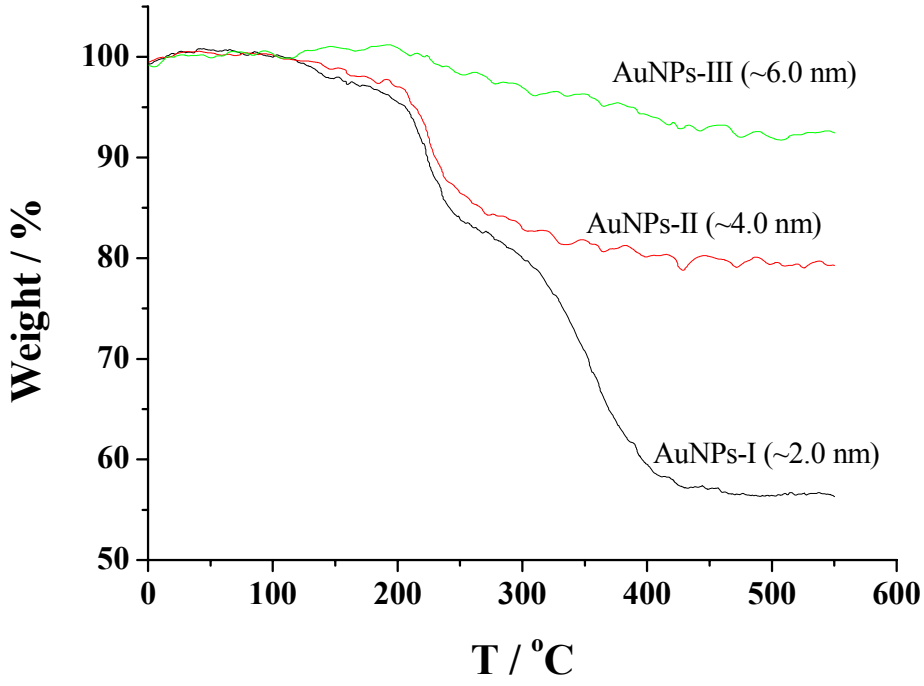

Figure S3: TGA graph of small and large gold nanoparticles.

S4: ICP, AAS and UV-Vis. characterisation of Gd-loaded gold nanoparticles

Gd-loaded gold nanoparticles were characterised by ICP and AAS to determine the exact gold and gadolinium contents which were needed for relaxivity measurements and gold nanoparticle compositions. The Gd amount in Gd-loaded AuNPs was also determined by xylenol orange titration using UV-Vis. spectroscopy and the protocol is described below. The Gd-loaded AuNPs were digested by aqua regia before analysis by ICP, AAS and UV-Vis.

S4.1: Determination of [Gd^{3+}] using xylenol orange titration

Calibration curve for determination of [Gd^{3+}] in Gd-loaded AuNPs was set-up following the literature procedure.[2] Xylenol orange is a weak lanthanide chelating agent that can chelate with free gadolinium ions. Xylenol orange exhibits two absorption peaks at 434 nm and 576 nm in the absence of any lanthanide. In the presence of lanthanides, the intensity of the first peak at 434 nm decreases while that at 575 nm increases. The ratio between the intensities of the two peaks can be used for the quantitative determination of lanthanides (Gd^{3+} in our case). The UV-Vis. spectra of xylenol orange in the presence of various concentrations of Gd-atomic standard solutions and the calibration curve built using these spectra are shown in Figures S4 and S5, respectively.

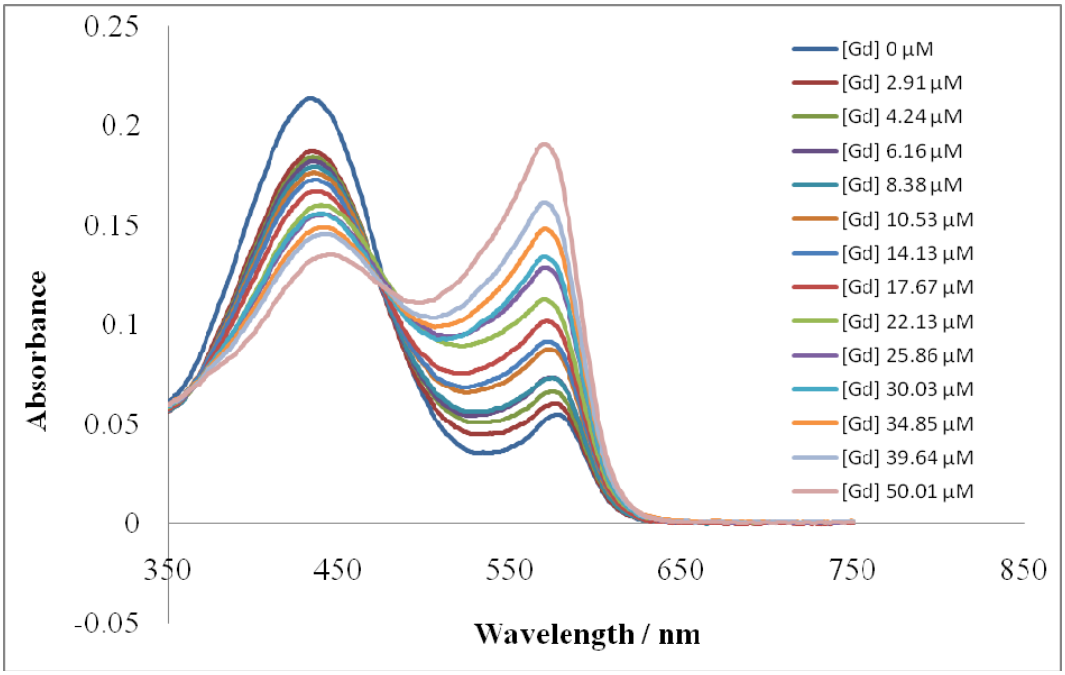

Figure S4: UV/Vis. spectra of xylenol orange in the presence of Gd atomic standard solution.

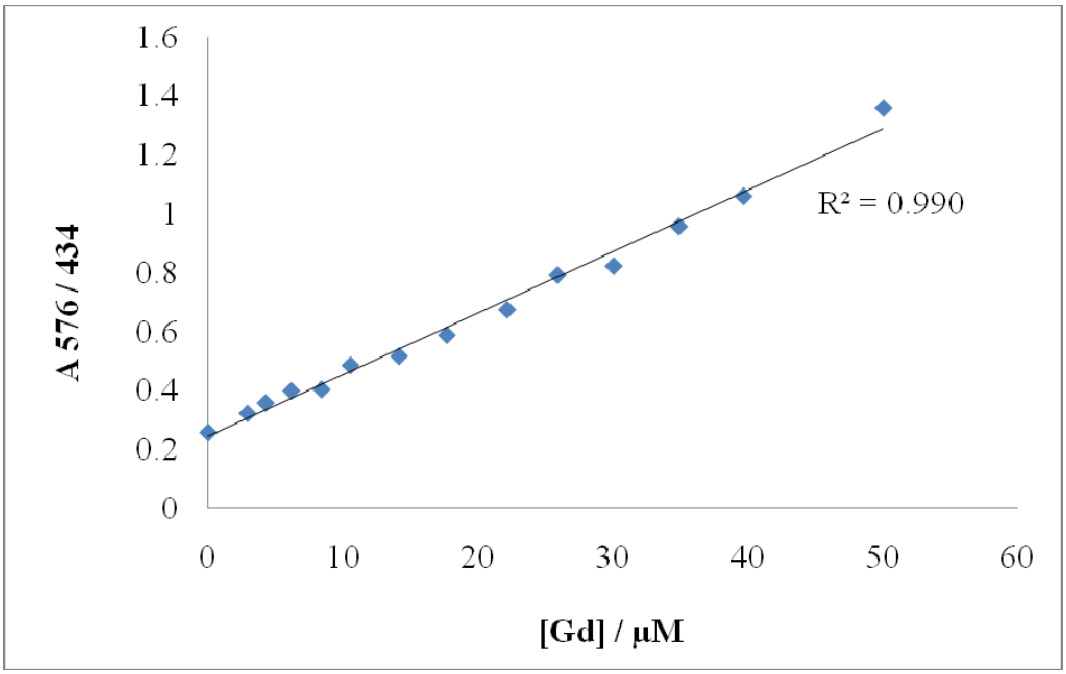

Figure S5: Calibration curve for the determination of $[Gd^{3+}]$.

The calibration curve shown in Figure S5 was used for the determination of [Gd^{3+}] in Gd-loaded AuNPs. The Gd-loaded-AuNPs were decomposed by treatment with aqua regia at ca. 80 ^{o}C for at least 24 h. Under these conditions, the AuNPs and organic ligands are destroyed and Gd^{3+} ions become free. The decomposed Gd-loaded-AuNPs were filtered using syringe filter, pH adjusted to 6 and diluted by the acetate buffer (pH 5.8) to make a solution for analysis [Gd^{3+}] was in the range 10-50 μM. The unknown concentration of Gd in this solution was determined by adding a 30 μL aliquot to 0.4 mL of xylenol orange and recording UV-Vis spectrum. From the ratio of absorbance at 434 nm and 576 nm, the [Gd^{3+}] could be determined using the calibration curve. For example, in 5.0 mg of Gd-loaded AuNPs, 0.51 mg of Gd content was determined by this method. Using this method, Gd-loaded AuNPs were found to contain ca. 10.13 wt % Gd (Table S2).

The ICP, AAS and UV-Vis. data for small and large gold nanoparticles is shown in Table S2.

Table S2: ICP and AAS data for small and large gold nanoparticles

Technique	**Element**	**AuNP diameter / nm**	**Composition / %**
ICP	Gd	~2.0	10.95
		~4.0	4.21
		~6.0	2.57
UV/Vis.	Gd	~2.0	10.13
		~4.0	4.39
		~6.0	2.32
Atomic absorption spectroscopy	Au	~2.0	45.64
		~4.0	70.35
		~6.0	82.25

S5: TEM analysis of AuNPs

The TEM analysis was done to determine the diameter of gold nanoparticles and level of aggregation. The TEM pictures of AuNPs-**I**, **II** and **III** are represented in Figure S6, which clearly shows well dispersed AuNPs. The diameters of gold core in AuNPs-**I**, **II** and **III** were found 1.75 ± 0.42 nm, 3.74 ± 0.55 nm and 6.05 ± 1.07 nm, respectively.

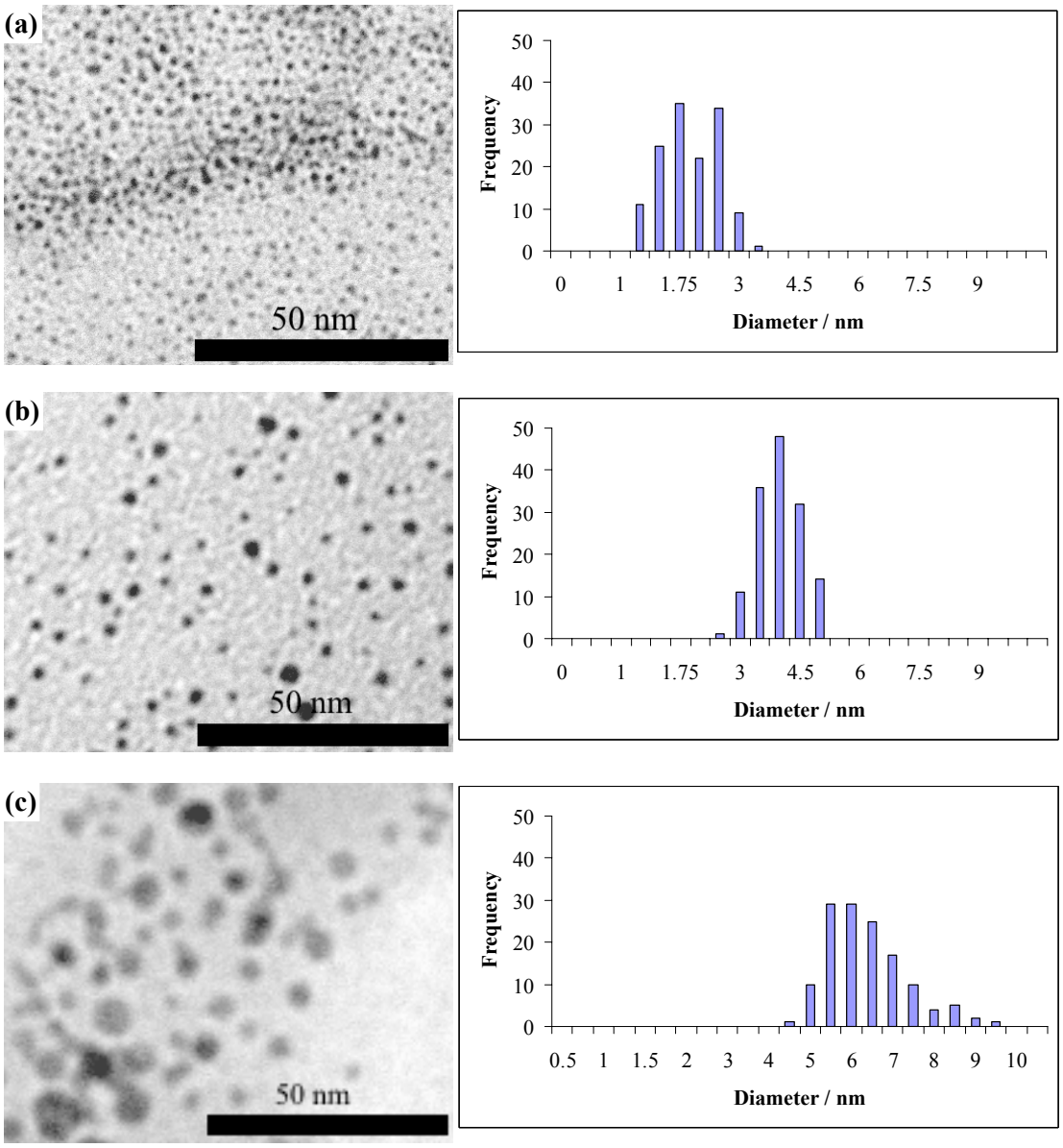

Figure S 6: TEM images and histograms for AuNPs-I (a), AuNPs-II (b) and AuNPs-III (c)

S6: UV-Vis. spectra of Gd-loaded AuNPs with and without polyelectrolyte coating

The UV-Vis spectra of gold nanoparticles did not exhibit any shift in plasmon band after coating with polyelectrolyte as shown in Figure S6.

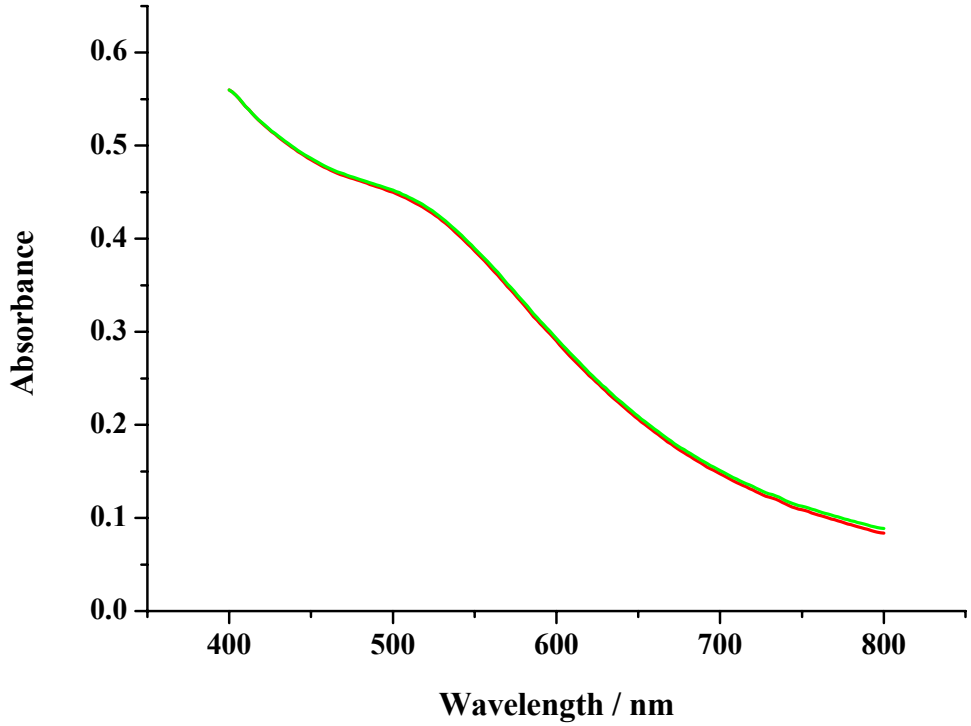

Figure S7: UV-Vis spectra of Gd-loaded AuNPs without PEI coating (green) and with PEI (red) coating.

S7: TEM analysis of Gd-loaded AuNPs with polyelectrolyte coating

(Average diameter = 1.77 ± 0.43)

TEM analysis of Gd-loaded gold nanoparticles after coating with polyelectrolytes did not show any aggregation. The TEM image and histogram of the Au core size distribution in PEI-**I**-coated-Gd-loaded AuNPs is shown in Figure S7.

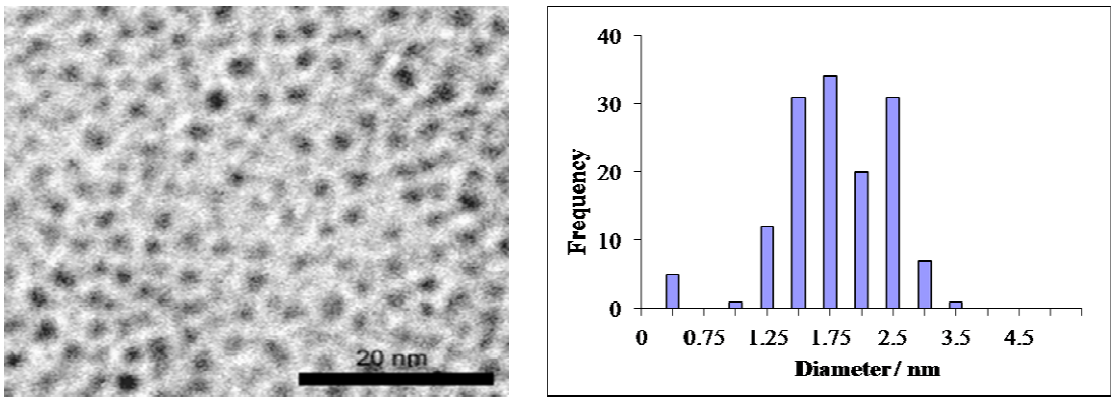

Figure S8: TEM and histogram of PEI-I-coated Gd-loaded AuNPs.

S8: References

1. J. W. Chen, F. P. Auteri, D. E. Budil, R. L. Belford and R. B. Clarkson, *J. Phys. Chem.*, 1994, **98**, 13452-13459.

2. A. Barge, G. Cravotto, E. Gianolio and F. Fedeli, *Contrast Media Mol. Imag.*, 2006, **1**, 184-188.