Magnetic Drug Targeting: An Analytical Model for the Influence of Blood Properties on Particle Trajectories

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Abstract:
Investigations on the behaviour of superparamagnetic nanoparticles under the influence of a high gradient magnetic field in the vascular system is required for a better under-standing of magnetic drug targeting. The influence on the particle transport of the non-Newtonian and Newtonian properties of blood as well as the influence of the heart rate was therefore studied. A analytical model was developed and the calculation of particle trajectories is presented and evaluated. The results show that the non-Newtonian properties of the blood have a positive influence on the number of retended nanoparticles. The calculations also showed that the number of retained nanoparticles was lower in oscillatory flow profile than in steady flow. The influence of the heart rate can be neglected for Womersley numbers smaller than 1.5.

Zusammenfassung:
Untersuchungen zum Verhalten von superparamagnetischen Nanopartikeln im vaskulären System unter Einwirkung eines starken Flussdichtegradienten sind notwendig um ein besseres Verständniss für das magnetische Drug Targeting zu erreichen. Aus diesem Grund wurde der Einfluss der Newtonschen und nicht-Newtonschen Strömungseigenschaften des Blutes sowie die Auswirkung des Herzschlages auf den Partikeltransport untersucht. Ein analytisches Model, welches die Berechnung der Partikeltrajektorien bei verschiedenen Strömungsbedingungen erlaubt wird dargestellt und ausgewertet. Die Berechnungen zeigen, dass sich die nichtnewtonschen Eigenschaften des Blutes positiv auf die Menge der, durch das Magnetfeld, angelagerten Partikel auswirken. Ebenfalls kann gezeigt werden, dass durch den Herzschlag weniger Partikel angereichert werden können. Der Einfluss des Herzschlages verschwindet für Gefäße mit einer Womersleyzahl kleiner als 1.5.

Résumé:
Afin de mieux comprendre le ciblage des drogues magnétiques, des recherches sur le comportement des nanoparticules super paramagnétiques soumises à de grands gradients de champ magnétique dans le système vasculaire est requis. L'influence du rythme cardiaque ainsi que des propriétés Newtoniennes et non Newtoniennes du sang sur le transport des particules, ont donc été étudiées. Un modèle analytique a été développé et le calcul des trajectoires des particules est présenté et évalué. Les résultats montrent que les propriétés non Newtoniennes du sang ont une influence positive sur le nombre de nanoparticules en rétention. Les calculs montrent aussi que le nombre de nanoparticules retenues est inférieur dans le cas d'un profil d'écoulement oscillatoire que pour un écoulement établi. L'influence du rythme cardiaque peut être négligée pour des nombres de Womersley inférieurs à 1.5.

Key words: magnetic drug targeting, cancer, magnetic nanoparticle, magnetostatic, biomagnetics

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satile flow profiles can be investigated. Experiments with animals have shown that magnetic drug-targeting is feasible [1, 27, 28]. Furthermore, the construction of targeting magnets is easy with the help of the calculated particle trajectories. Since the calculations are very fast to carry out, the optimal location of the magnet can be deter-mined. However, for physical reasons it is not possible to generate local flux density maxima and thus local force maxima far away of the poleshoe. Therefore MDT is only feasible for the treatment of near surface tumors like breast cancer or tumors in the head area.

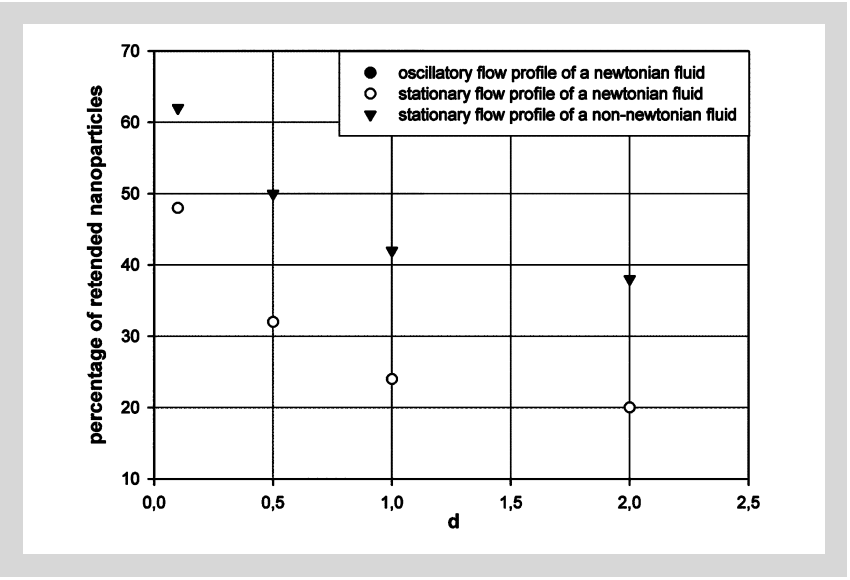

Figure 6:
Fraction of retained nanoparticles in relation to the distance, d, between field sources and vessel for different flow profiles.

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