Tungsten nanoparticle and polymer blends as novel coating for radiopaque resorbable inferior vena cava filters

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Background

Deep vein thrombosis (DVT) or pulmonary embolism (PE) affects about 900,000 individuals annually in the United States1. Currently, management is primarily through employment of anticoagulation therapy; however, placement of inferior vena cava filters (IVCFs) is recommended for patients with contraindications to anticoagulation. Absorbable IVCFs constructed with poly-p-xylene (PPDO) eliminate the need for filter retrieval. Radiolucency of PPDO-IVCFs can be improved with radio-enhancing nanoparticles (NPs).

Methods

WNPs were synthesized by thermal decomposition of tungsten acid with oleic acid, oleylamine, and 1-octadecene as stabilizers under an Ar blanket. Physicochemical properties of collected WNP were characterized by transmission/scanning electron microscopy (TEM/SEM), micro-computed tomography (CT), dynamic light scattering (DLS) and powder X-ray diffraction (XRD) patterns. PPDO sutures and IVCF filters were coated with WNP+PHB, PCL, and PVP using a wet-dipping technique.

In vitro cell viability and hemolysis assays were done using immortalized human vascular endothelial cells (EC-RF24) and erythrocytes from laboratory rats, respectively. W+PHB and W+PHB+PCL+PVP IVCFs were deployed in separate pig models, monitored, and imaged using CT for 12 weeks. Post-mortem histology analyses were done to investigate possible systemic and local effects of WNP+polymer-embedded IVCFs.

Results

(A) TEM, (B) SEM, (C) X-ray, and (D) micro-CT images of WNP and WNP-coated sutures. (E) Distribution of the measured diameters from TEM. (F) XRD pattern of W.

Fig. 3. Physicochemical characterization of WNP. % Cell Viability (% Treated Media) and % Lysis (% Treated Media) of EC-RF24 cells measured using alamarBlue assay after 24 h incubation in varying ratios of treated cell culture media.

Fig. 4. (A) Hemocompatibility showing the % blood lysis after incubation with the untreated and treated PPDO sutures. (B) In vitro cell viability of EC-RF24 cells after 24h incubation with untreated and treated PPDO sutures.

Conclusion

- In vitro cytotoxicity and hemolysis assay did not show any effects on W-IVCF.
- Biodegradable IVCFs coated with WNP+PHB+PCL+PVP reinforcement can be fully visualized in pigs under fluoroscopy and CT for real-time image-guided deployment and monitoring over time.
- Despite good visualization in fluoroscopy and CT from deployment until week 12, lumen of the WNP+PHB+PCL+PVP-coated IVCF pig did not seem to recover from initial inflammation as reflected by closed and necrotic lumen.

Future Direction

Although the addition of biocompatible polymers, PHB, PCL, and PVP enhanced the attachment of WNP which resulted in increased radiopacity, localized inflammatory response was also observed in histology. Therefore, alternative polymers are currently being investigated to increase the surface roughness of PPDO and attachment of the nanoparticles. In addition, other high-Z nanoparticles, such as zirconium and gadolinium, are also being explored as potential radiopaque agents for IVCFs.

References

4) Damasco et al. ACS Biomater Sci Eng. 2022; 8:1676-1685

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