

附錄

新微型機械人集群平台的運作原理

1. 首先通過導管輔助輸送和部署微凝膠集群到動脈瘤頸部位置，藉此提供一條跨越生物屏障的「通道」，保護微型機械人免受免疫系統的影響。
2. 在超聲波和 X 光透視影像的實時引導下，經過編程的外磁場會引導和匯集微機械人集群至動脈瘤位置。
3. 隨後，通過導管注入酸性緩衝溶液，啟動微凝膠之間的自粘機制，將微凝膠焊接成一個整體。
4. 過程完成後，導管和磁場可被移除。

Appendix

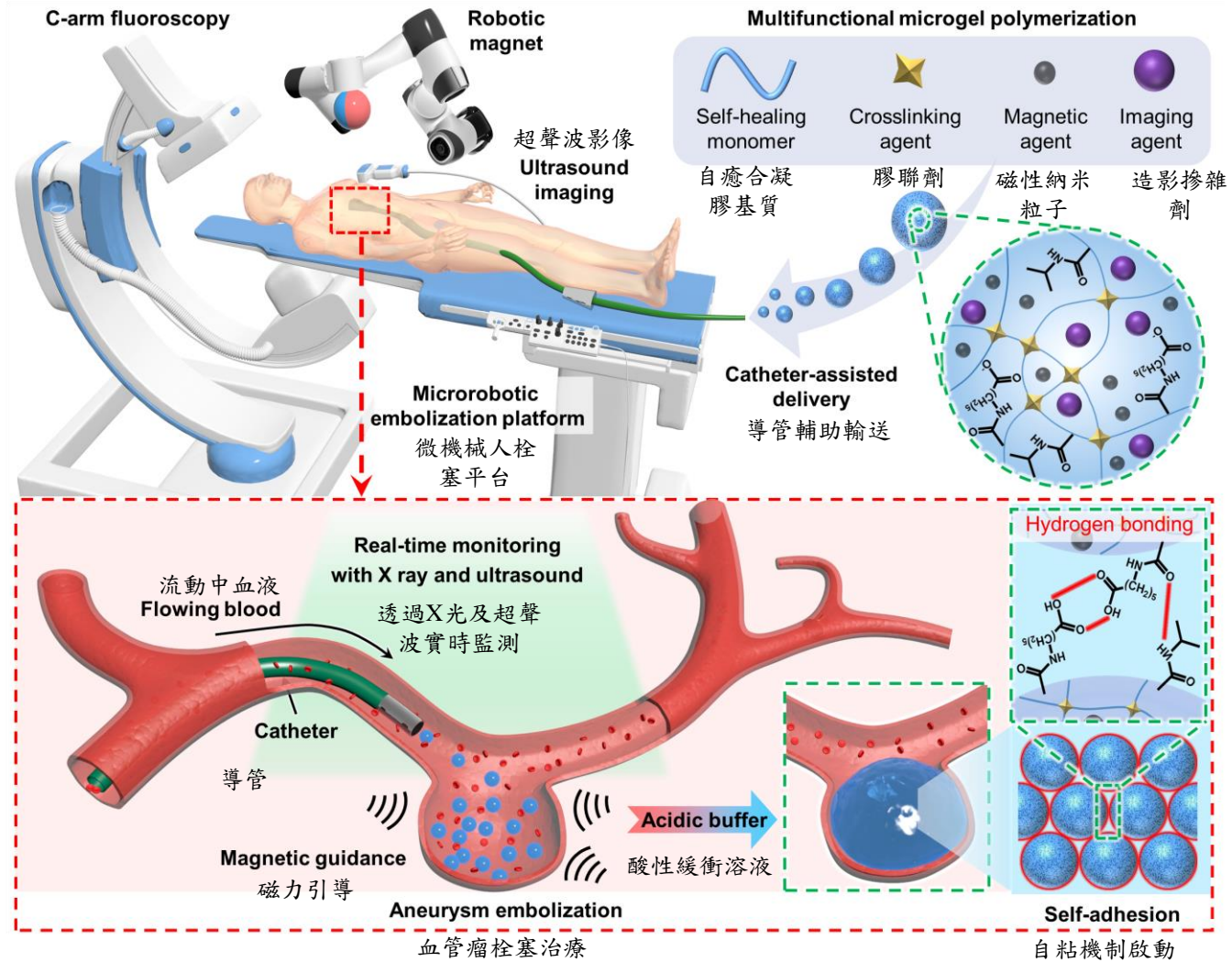
How does the newly developed swarming microrobotic platform work?

1. It is initiated by catheter-assisted delivery and the deployment of swarming microgels to the aneurysm neck, which provides a highway across biological barriers and protects microrobots from the immune system.
2. A programmed external magnetic field is applied to navigate and concentrate swarming microrobots into the aneurysm sac under the real-time guidance of ultrasound and fluoroscopy imaging.
3. An acidic buffer solution is injected via a catheter to activate a self-adhesive mechanism among the microgels, welding them into a single entity.
4. The catheter and magnetic field are removed.

C型機械臂X光透視影像裝置

機械人
磁控裝置

多功能凝膠聚合



一種介入手術輔助的微凝膠集群系統，可在醫療影像設備實時引導下完成動脈瘤的按需栓塞，以彌補傳統栓塞療法在填充與靶向效率上的不足。集群系統的每個基本構件是直徑在微米級的凝膠微球，其主要由pH響應型自癒合水凝膠基質、磁性納米顆粒和造影摻雜劑構成。

An interventional catheterisation-integrated swarming microrobotic platform for real-time medical imaging guided embolisation of aneurysm, aiming to address the bottlenecks of conventional embolisation therapy in filling and targeting efficiencies. Each building block of the microrobotic swarm is a micro-sized sphere composed of pH-responsive self-healing hydrogel matrix, magnetic nanoparticles and imaging dopants.

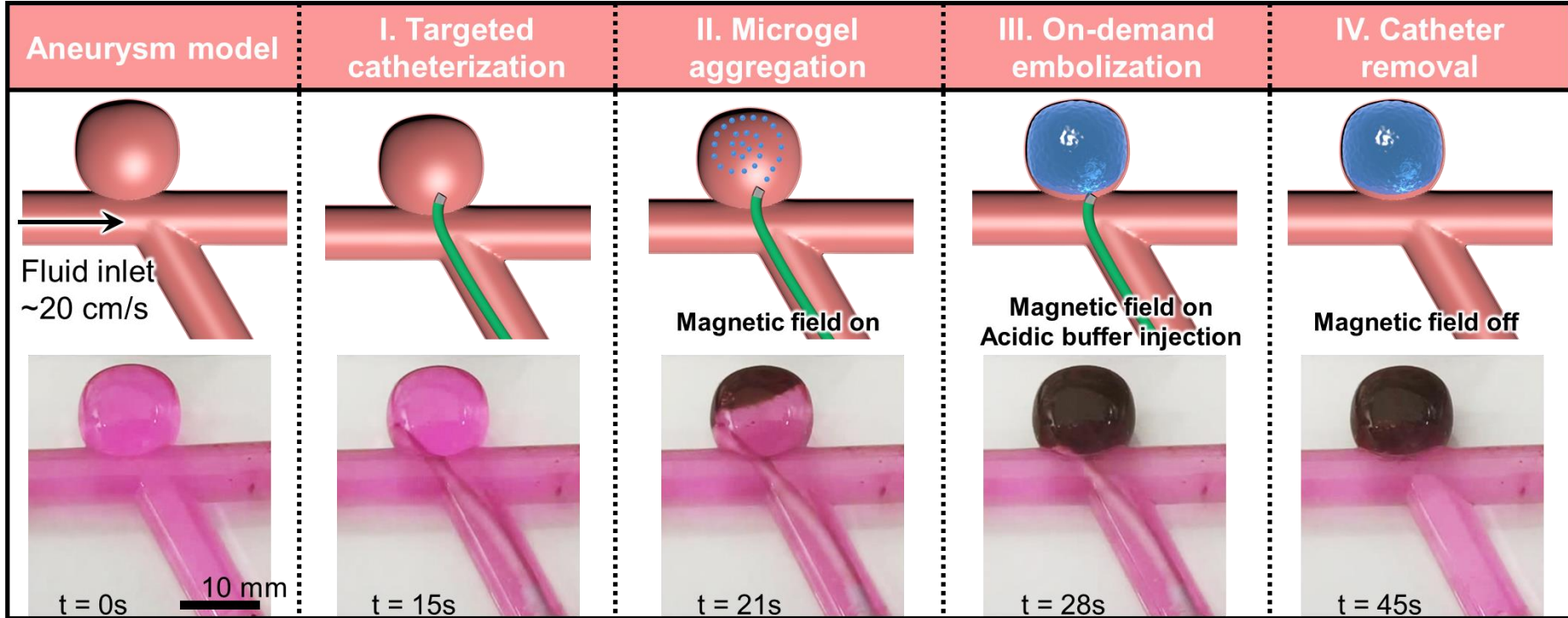
動脈瘤模型

靶向導管介入

磁控下
微型膠聚合

溫和酸性刺激
引發按需栓塞

導管及磁場移除



自粘附微凝膠集群在動脈瘤模型中定向栓塞示意圖與實驗結果，包括（I）靶向導管介入，（II）微凝膠集群釋放並在磁控驅動下在動脈瘤模型腔內聚合，（III）溫和酸性刺激引發按需栓塞，和（IV）移除導管與磁場。

The schematic and experimental results of swarming self-adhesive microgels enabled on-demand embolisation in aneurysm model, including targeted catheterisation (I), deployment and active accumulation of swarming microgels into aneurysm sac under the actuation of robotic magnet (II), on-demand embolisation via mild acid stimulus (III), and the removal of catheter and robotic magnet (IV).