

Engineering Safer and More Predictable Brain Drug Delivery

T. Yuan¹, N. Pecco², W. Zhan³, S. Galvan¹, R. Secoli¹, M. Riva⁴, L. Bello⁵, A. Falini², F. Rodriguez y Baena¹, A. Castellano², and D. Dini¹

¹Imperial College London, UK
²San Raffaele University, Italy
³University of Aberdeen, UK
⁴Humanitas Research Hospital, Italy
⁵Università degli Studi di Milano, Italy

- ✔ >90% overall prediction accuracy
- ✔ Validated in 6 *in vivo* sheep experiments
- ✔ Personalised medicine & translational impact

IMPERIAL

Brain diseases & socioeconomic burden

Dementia, Strokes, Parkinson's, Brain tumors, ...

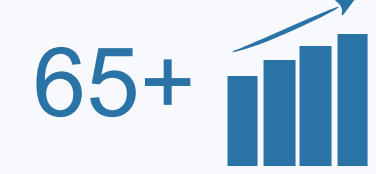


1 in 6 People affected Globally

Linked to 20% of UK deaths



Annual cost > £112B (UK)
 Dementia \$1.3T/y (Global)

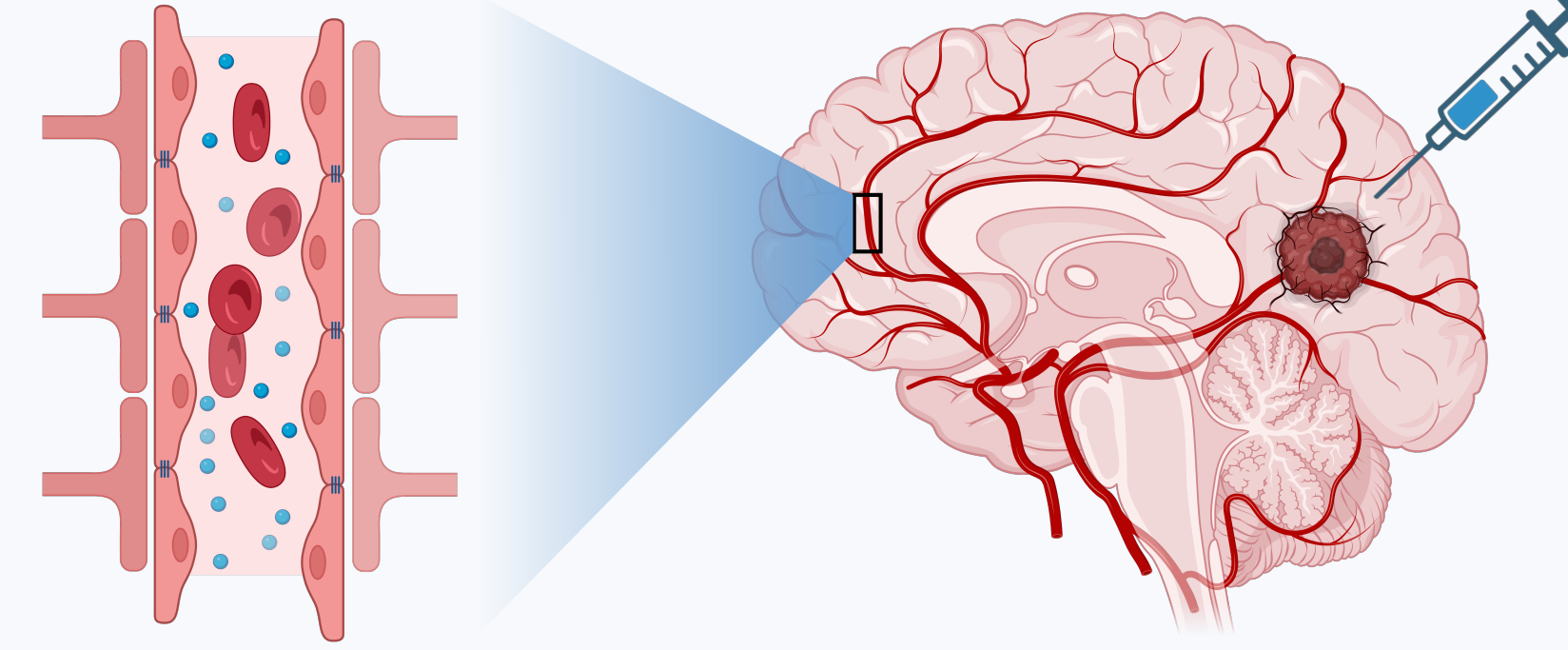


65+
 18.65% population (UK) & Increase sharply with age

Key challenge in brain drug therapy

Intravenous injection ☹️

Direct Drug Injection 😊?



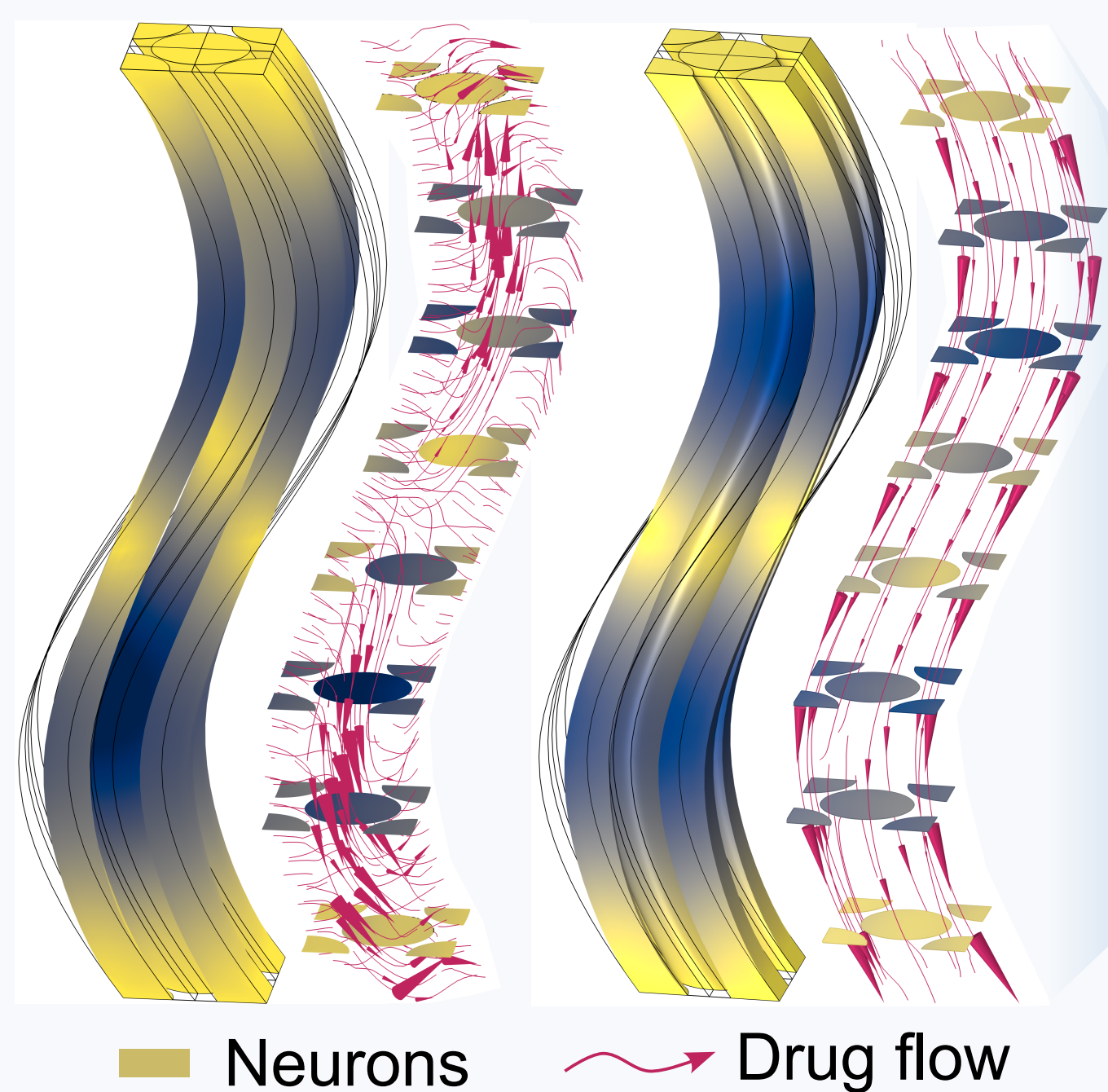
Blood-Brain Barrier (BBB): blocks >98% drugs from entering the brain

- Promising ✔️
- unpredictable ❌
- unreproducible ❌

Reason:
 Brain's fluidic system is extremely complex

Our Solution: A highly accurate physics-based prediction tool

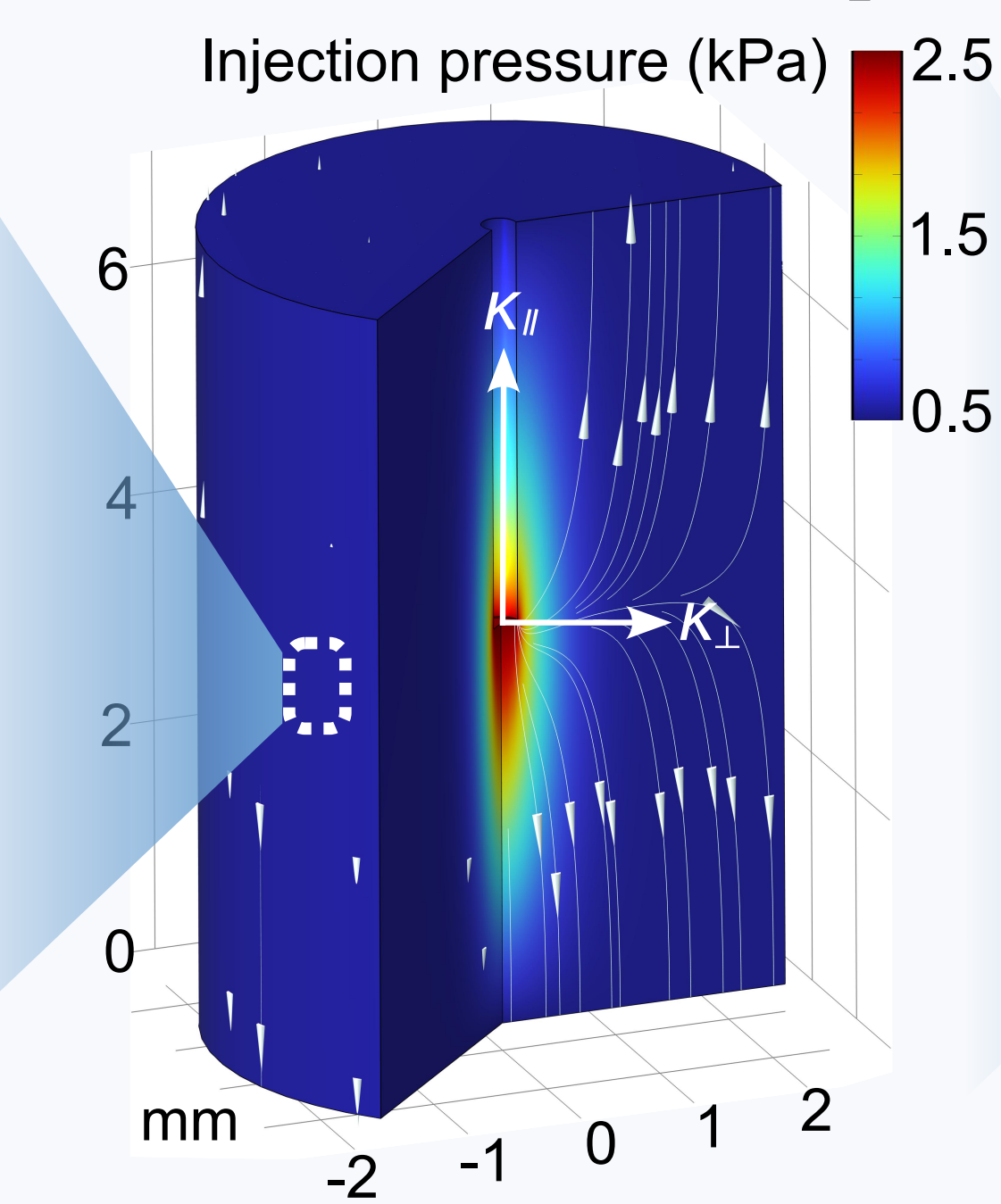
Cellular Scale Model [μm]



Neurons Drug flow

Understand how drugs move around neurons

Tissue Scale Model [mm]

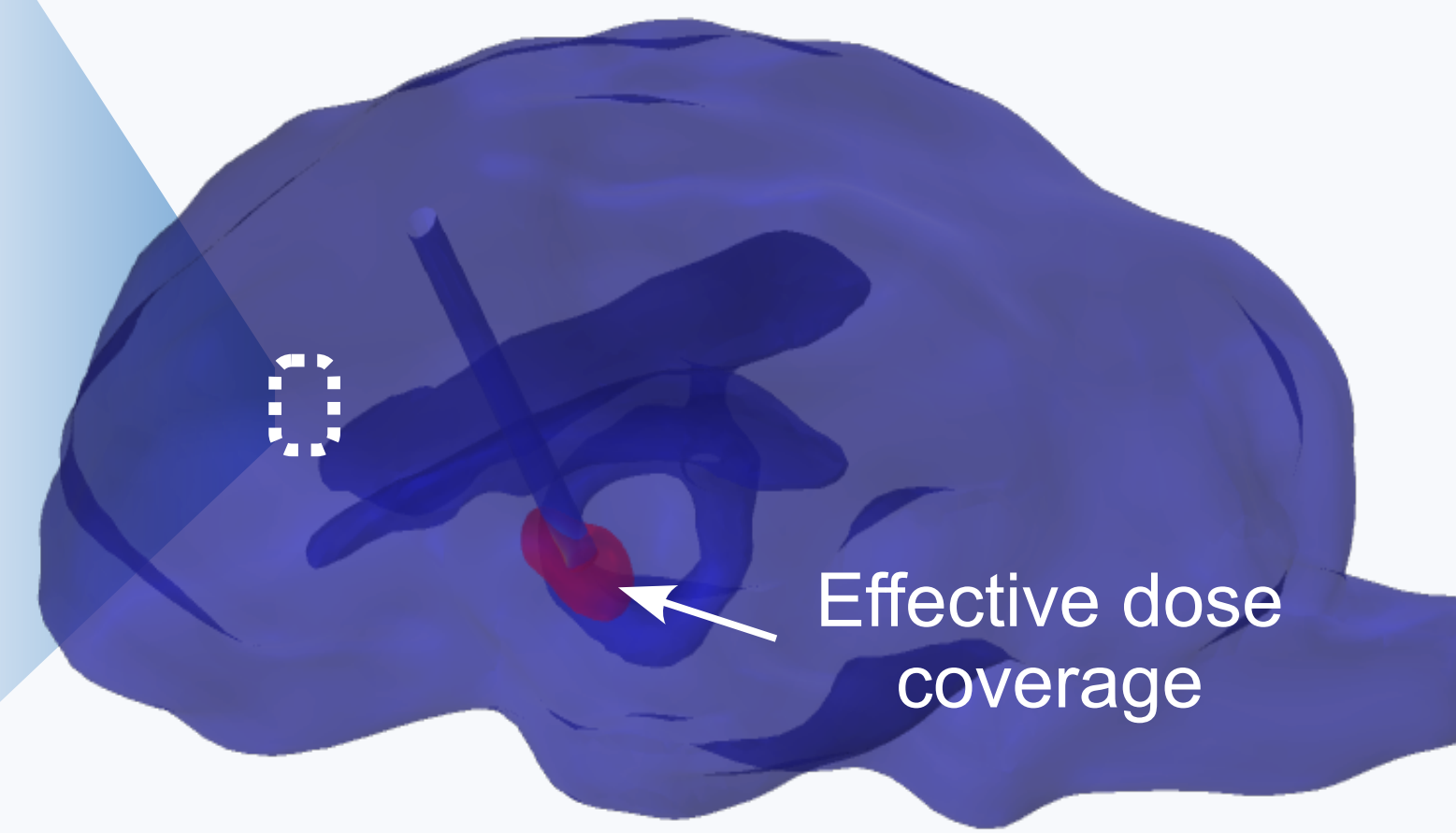


Model how drugs spread through brain tissues

Organ Scale Model [cm]

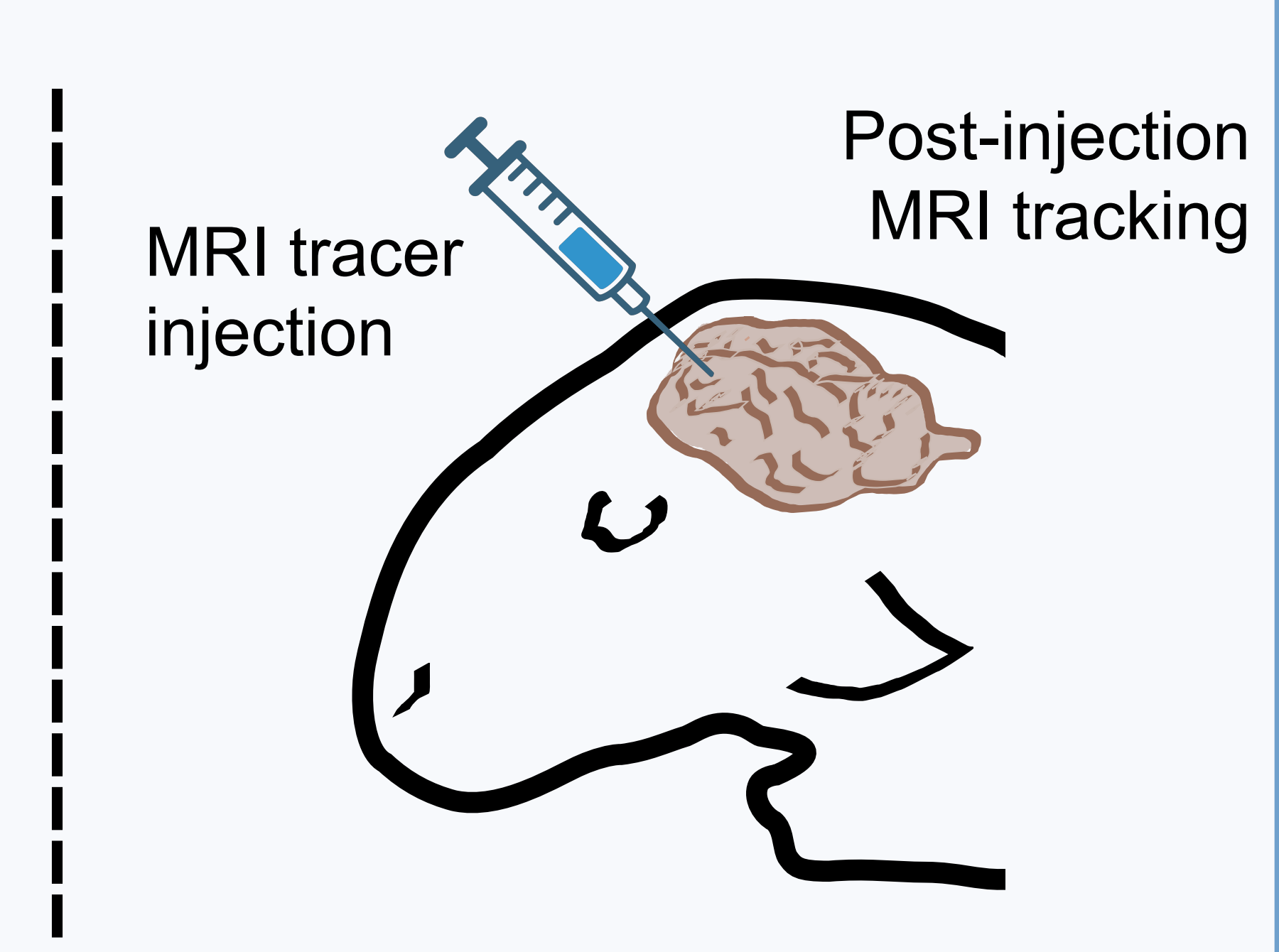
$$\frac{\partial c}{\partial t} = \nabla \cdot (D \nabla c) - \nabla \cdot (v c)$$

Built on rigorous mathematical models



Predict drug distribution across the whole brain

Tested in Animal Studies (sheep)

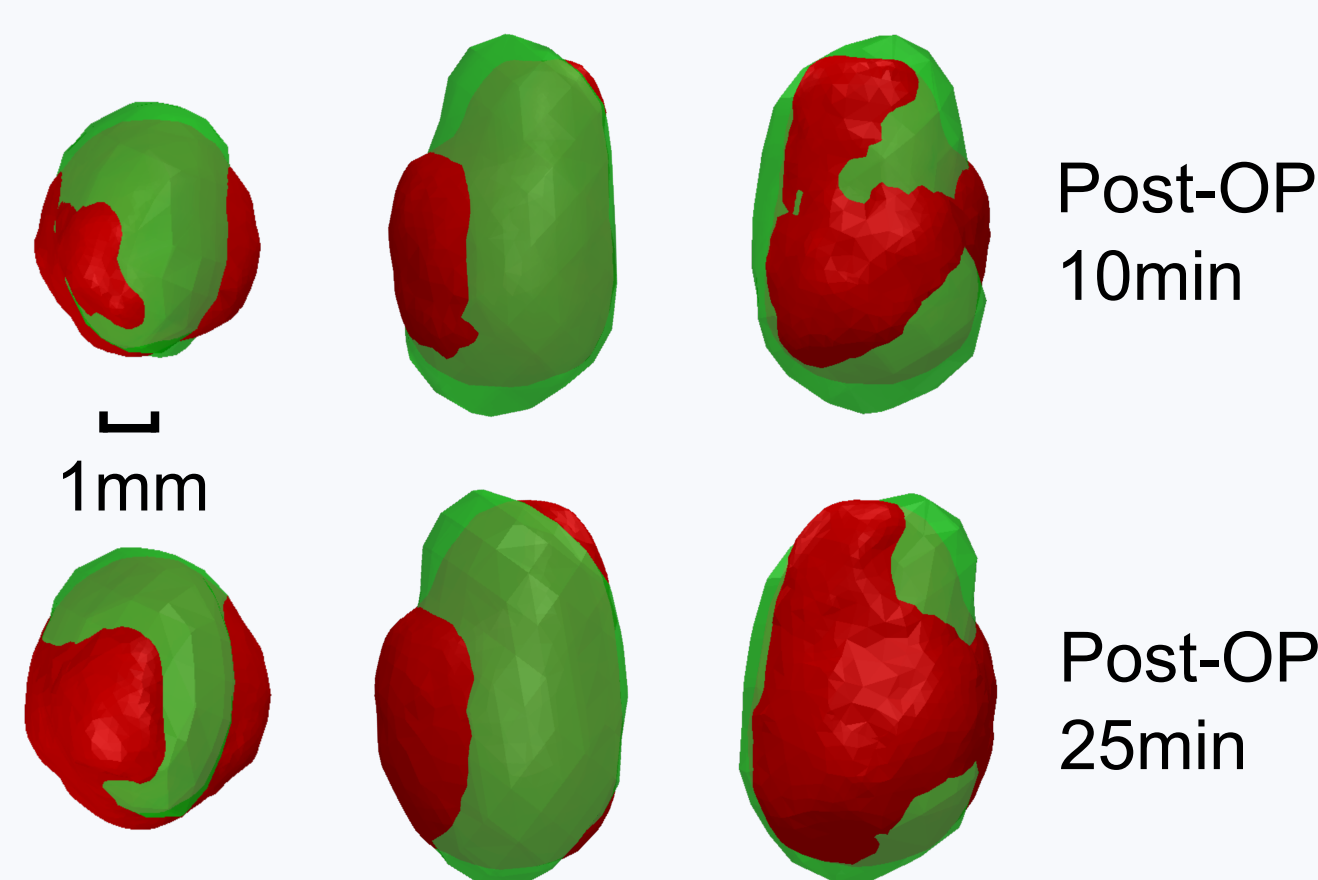


In vivo brain infusion experiments
 6 independent experimental groups

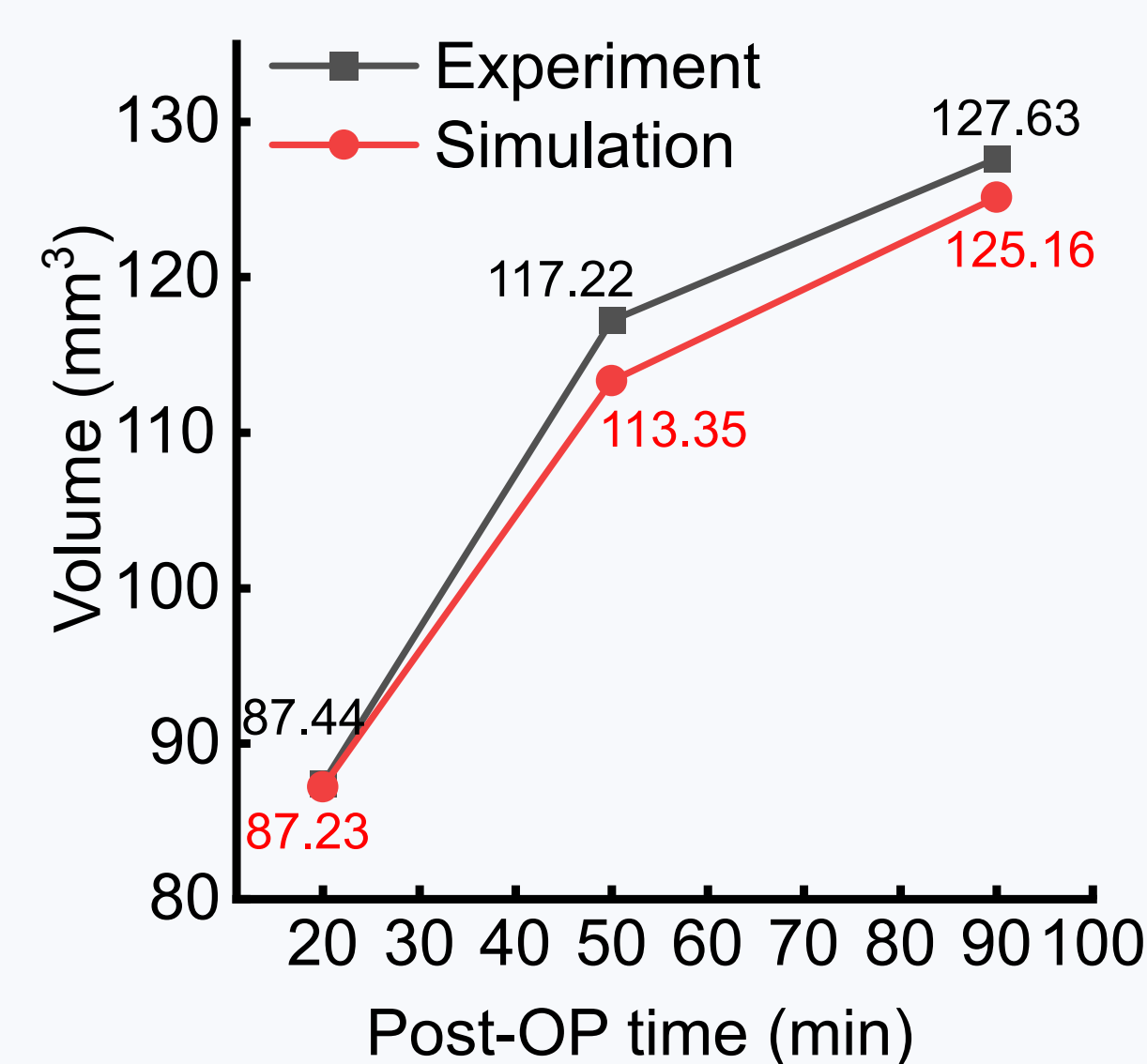
Does it work?

>90% overall predictive accuracy (6 independent groups)

e₁ view e₂ view e₃ view



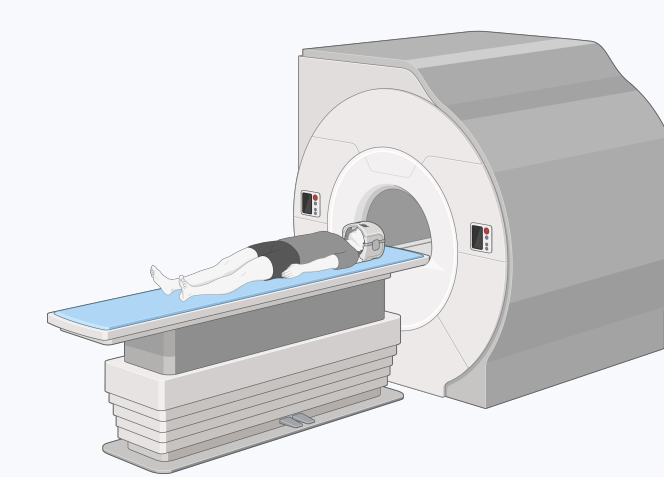
Shape & Orientation comparison (Group 1)



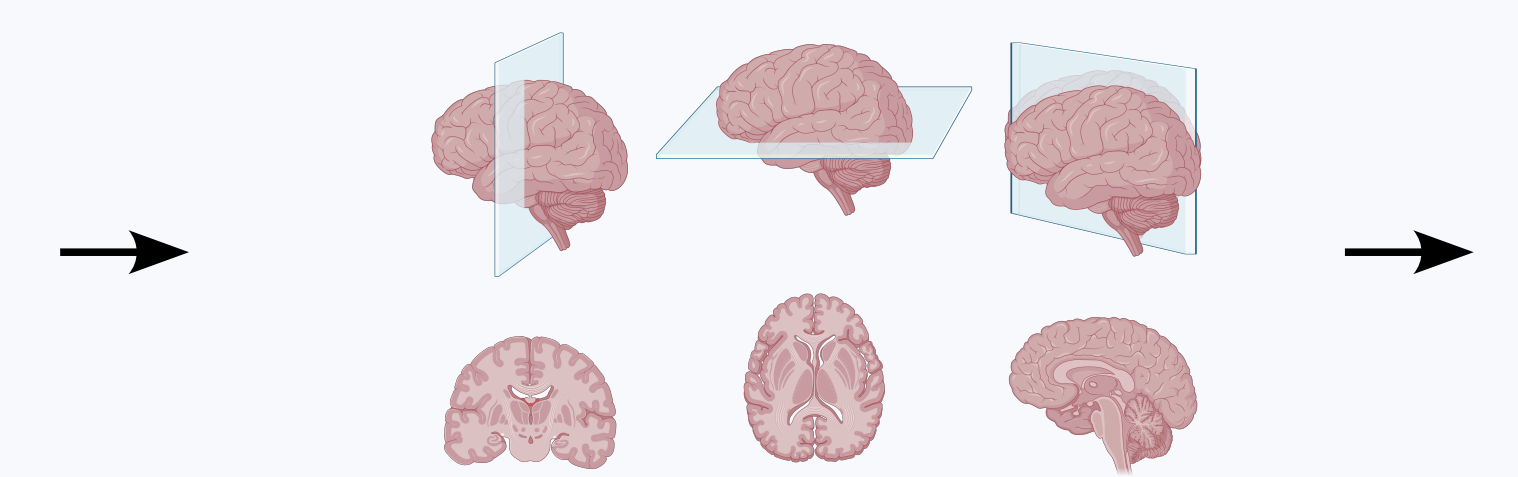
Size comparison (Group 4)

How can it be used?

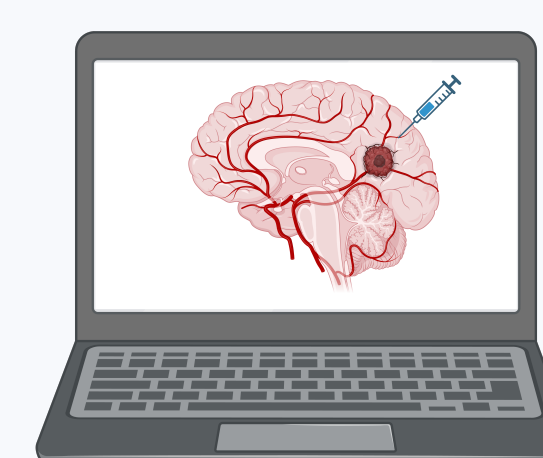
Test and optimise procedures **virtually** before treatment.



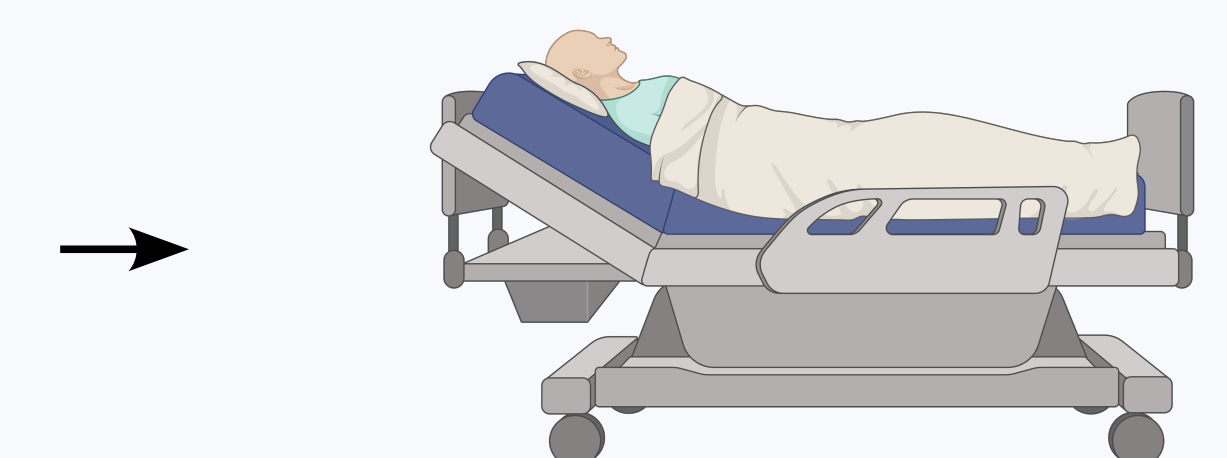
Step 1: MRI Scan



Step 2: Brain 3D Reconstruction



Step 3: Virtual Optimisation & Planning



Step 4: Model-guided Treatment

Impact

What does this mean for the NHS?

- Safer personalised neurosurgery
- More effective cancer treatment
- Reduced NHS waste from failed interventions



What does this mean for the UK and globally?

- Reduced long-term burden of brain disease in an ageing population
- More efficient and sustainable healthcare delivery
- Accelerated access to precision medicine
- UK leadership in advanced neurotechnology



Why this is credible?

1. Validated *in vivo* with >90% overall prediction accuracy
2. Supported by major UK and EU funders
3. Recognised through national and international awards



Medical Research Council



Conclusion

This new technology makes brain drug delivery **predictable, safer,** and more **cost-effective** - improving **patient outcomes,** saving **NHS resources,** and supporting the **UK's global leadership** in precision medicine

Learn more about my research

