Development of the clinical tool ‘NeuroTool’ to aid device sizing, ease of angiography, and liquid embolic compatibility

N. Mansoor[1], M. Benger[1], S. Sciacca[1], J. Siddiqui[1], P. Balasundaram[1], N. Kandasamy[1], T. Booth[1], J. Lynch[1]
[1]Kings College Hospital, Department of Neuroimaging, London, United Kingdom

ESMINT Congress 2022: Nice, France 7 – 9 September 2022.

Disclosures

No commercial funding for development.
The website is self-funded and free to use.

Introduction

- A great variety of neurointerventional devices now exist and practitioners may not be familiar with **compatibility** especially of newer devices. As procedures become more complex and guide catheters increase in size **more devices** can often be inserted into a single catheter lumen.
- Predicting in advance whether (i) they will **fit** and (ii) whether **angiography** can be performed can be non-trivial.
- If devices are unexpectedly incompatible they must be discarded, increasing **cost** of procedures.
- If 3 or more devices are used in a single lumen the problem is mathematically **complex** (a problem termed 'circle packing') and compatibility cannot be calculated by summation of the diameters.
- There is (was) no available method to predict in advance whether 3 or more devices will fit in a single lumen other than trial and error
- Aims: **Produce a model to predict device compatibility in terms of diameter, length, space for cerebral angiography, and liquid embolic usage.**

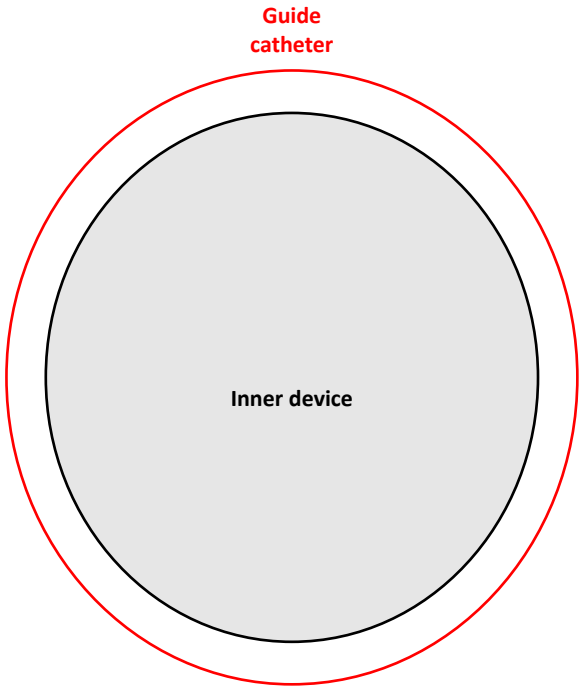
Methodology

- A **search** was made of all available commercial catalogues for devices made for interventional neuroradiology (catheters, balloons, stents etc.)
- A large **database** was compiled consisting of manufacturer provided and empirically observed data: on sizes, lengths, compatibility, DMSO compatibility.
- A computational **model** employing the *Matousek-Sharir-Welzl* algorithm was used to predict device fitting.
- An **app** was created and uploaded online to be used by clinicians.

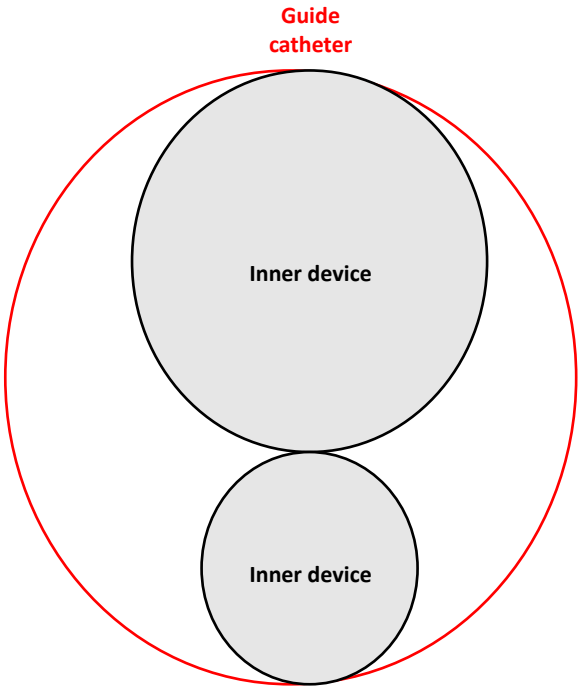
J. Matousek, M. Sharir, E. Welzl. A subexponential bound for linear programming. 1 July 1992. Mathematics, Computer Science. Algorithmica. DOI:10.1007/BF01940877Corpus ID: 877032

1 or 2 or devices

- Whether 1 2 devices will fit within another is a straightforward calculation.
- The only catch is that some catheters, e.g. Sofia Plus, require a larger lumen than their outer diameter would suggest (e.g. due to ovalisation). This value has to be used instead of the true outer diameter.



1 device



2 devices

3 or more devices

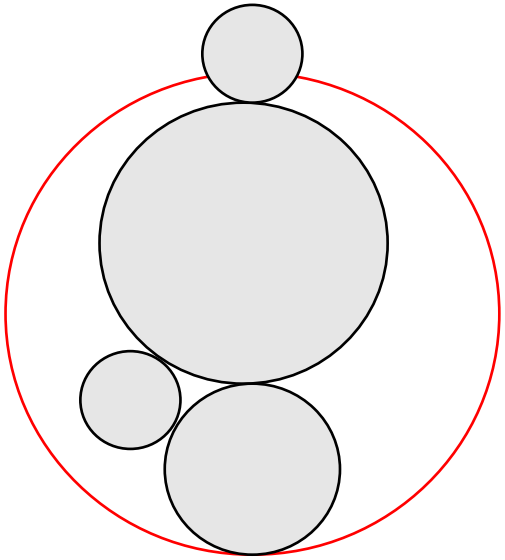


Fig. 1

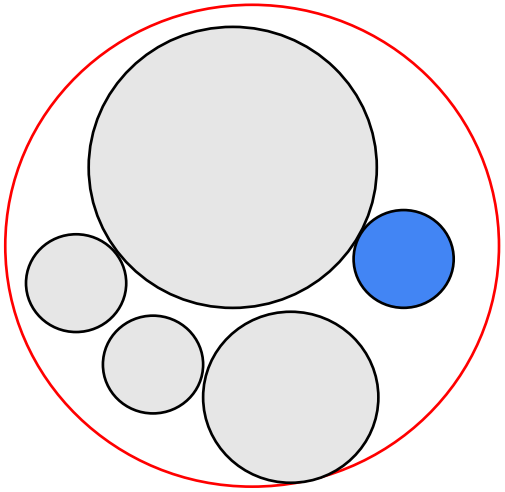


Fig. 2

- When 3 or more devices are inserted in to a larger device there is **no geometric formula** to determine whether or not they will fit.
- There are different ways that the devices can sit beside each other: in some configurations the devices will fit in some they will not.
- This seems obvious but requires an algorithm to find an efficient pack.

3 or more devices

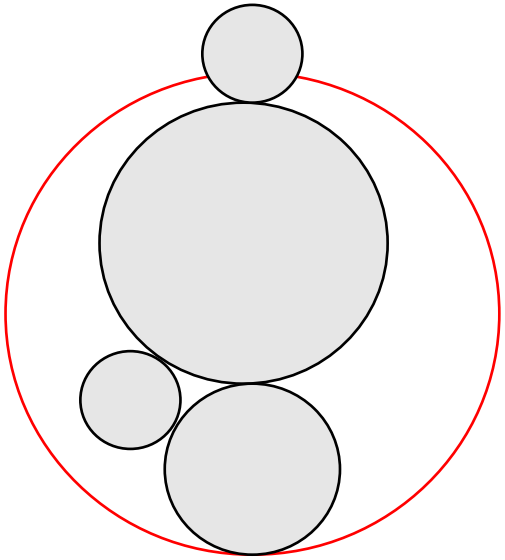


Fig. 1

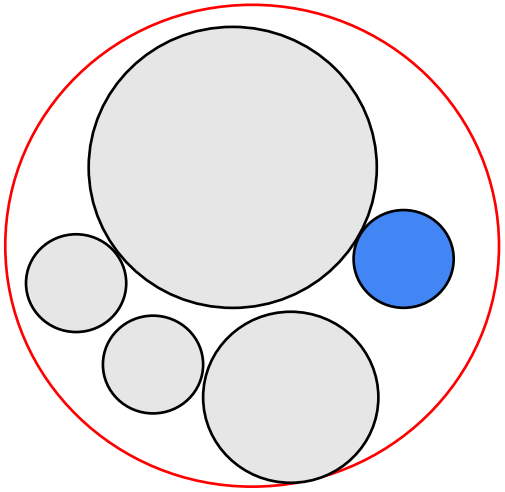


Fig. 2

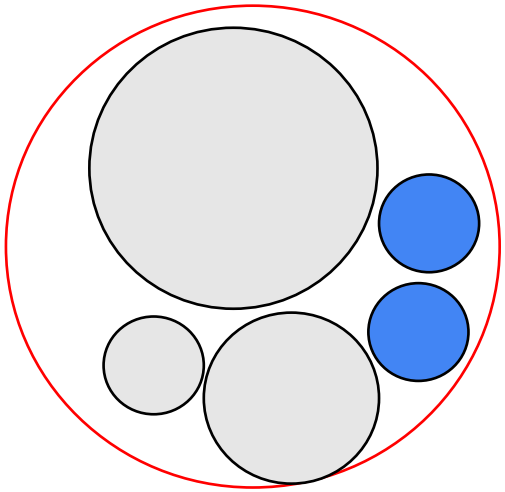


Fig. 3

- This configuration will change when further devices are added

3 or more devices

- The branch of mathematics generally known as "circle packing" is concerned with the geometry and combinatorics of packings of arbitrarily-sized circles
- In this instance an algorithm is needed to calculate the smallest diameter multiple arbitrarily sized circles can be '**packed**' in to (Fig 1).
- First the circles have to be packed efficiently together.
- When arranging circles the enclosing circle only changes when you move a circle that is tangent to the internal circles. The set of tangent circles is called the basis for the enclosing circle (Fig 2).
- A circle *a* encloses a circle *b* if and only if a's radius is **greater than or equal to b's radius** plus the distance between the two circles' centres:

$$r_a \geq r_b + \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}$$

- Using the Matoušek-Sharir-Welzl we iterate over the circles to calculate the basis until all the circles are covered (Fig 3).
- The algorithm is explained in detail here: https://observablehq.com/@lretondaro/msw-algorithm

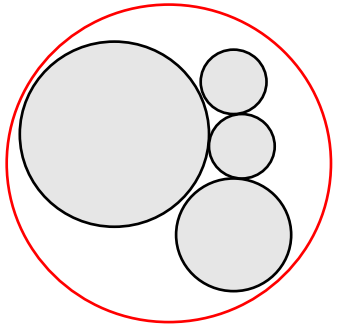


Fig. 1

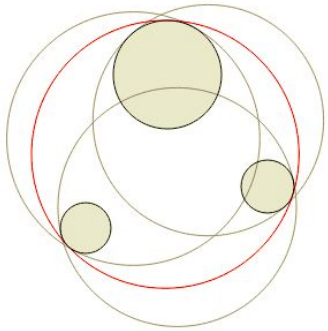


Fig. 2

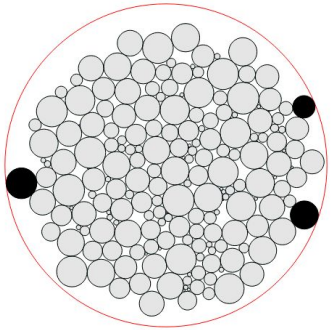
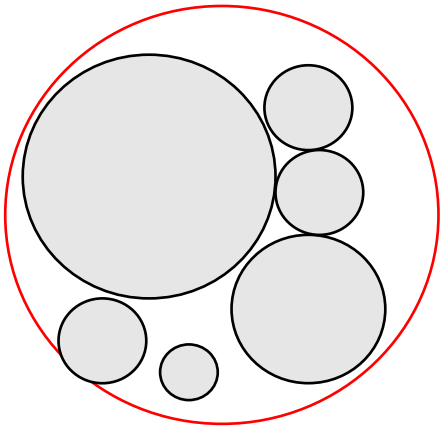
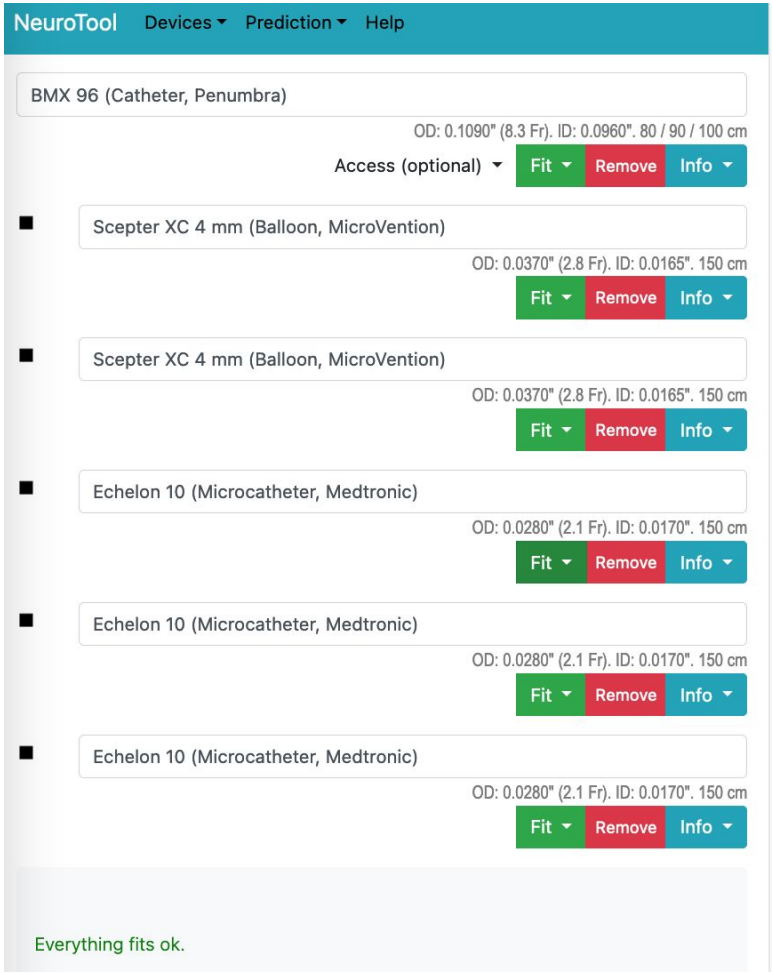


Fig. 3

Example

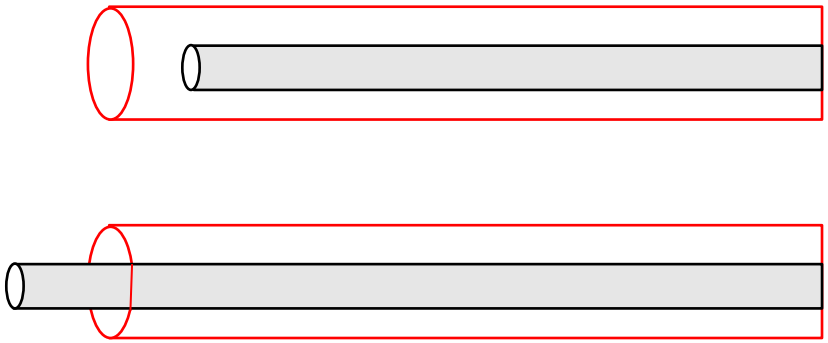
- Newer guide catheters such as the BMX 96 have **larger inner diameters** and can therefore fit more devices inside.
- The scenario presented opposite is an unlikely one but **all of these fit** within the BMX catheter (overleaf).
- It would however be impossible to predict this in advance non-algorithmically.

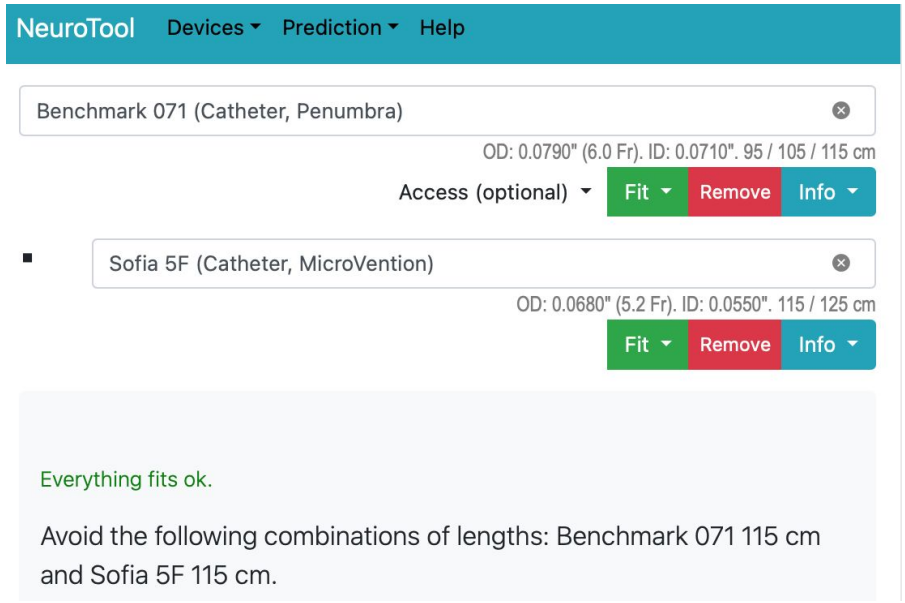




Length

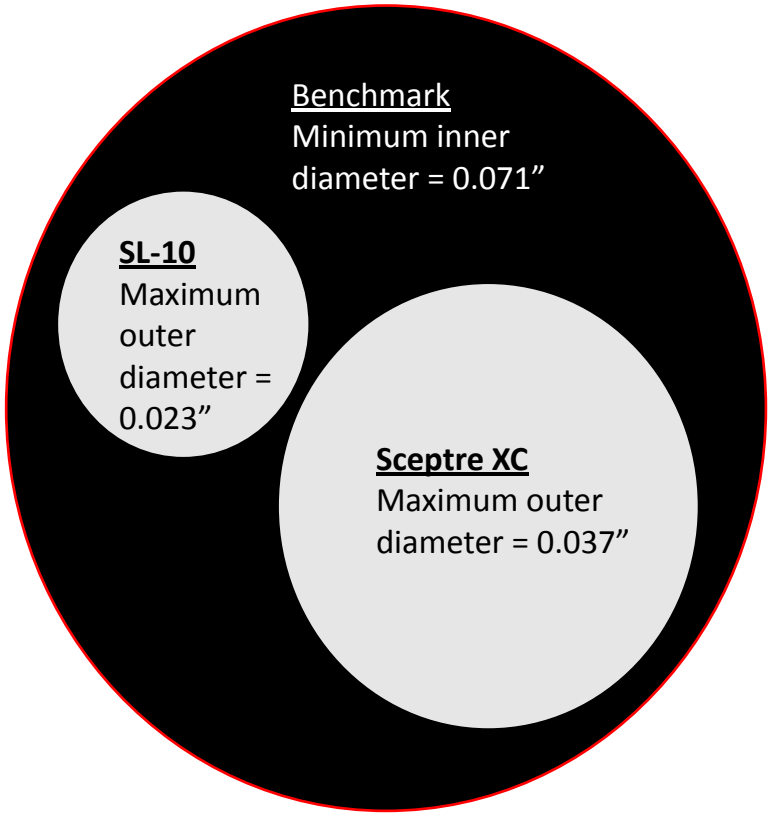
- It must also be considered if the inner device extends beyond the **length** of the outer device
- Otherwise the inner device will not extend beyond the outer and effectively be useless).





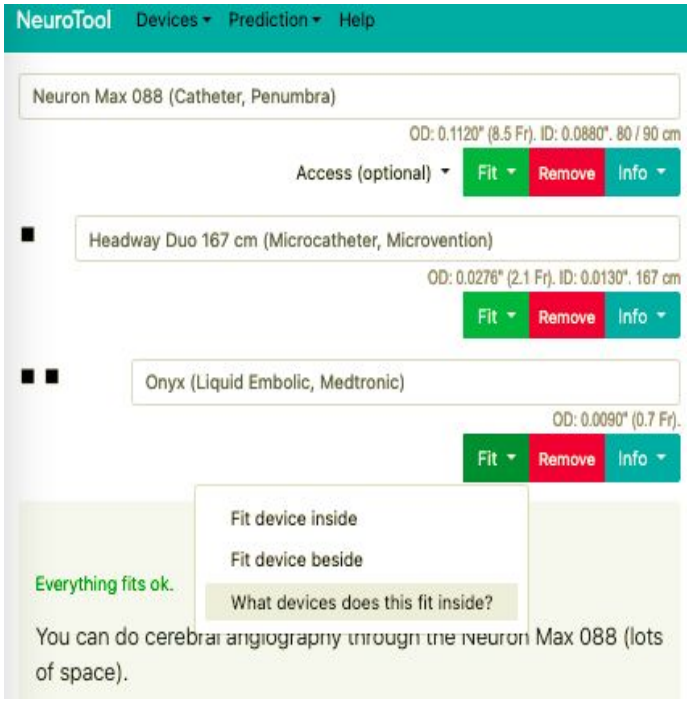
Angiography strength

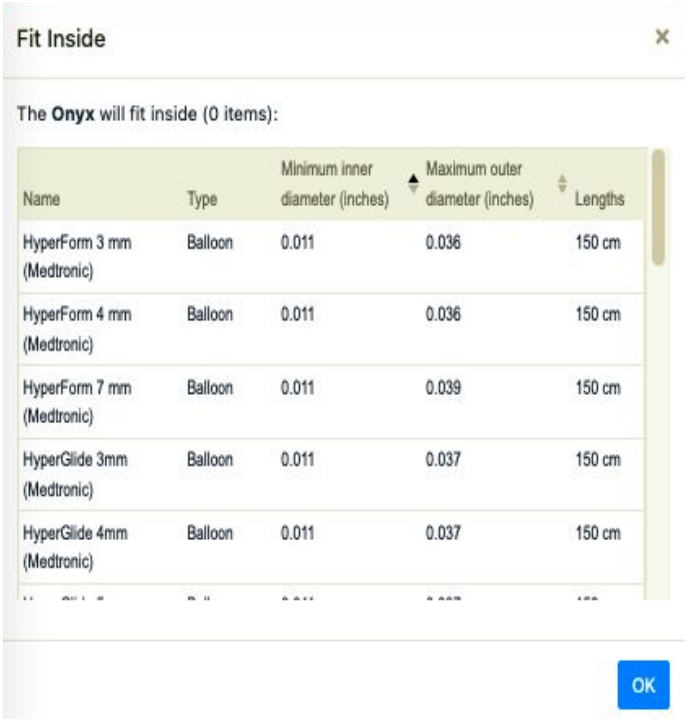
- The **angiography strength** is determined by the space left after summing the areas of the inner devices from the outer devices - the black area in the example opposite.



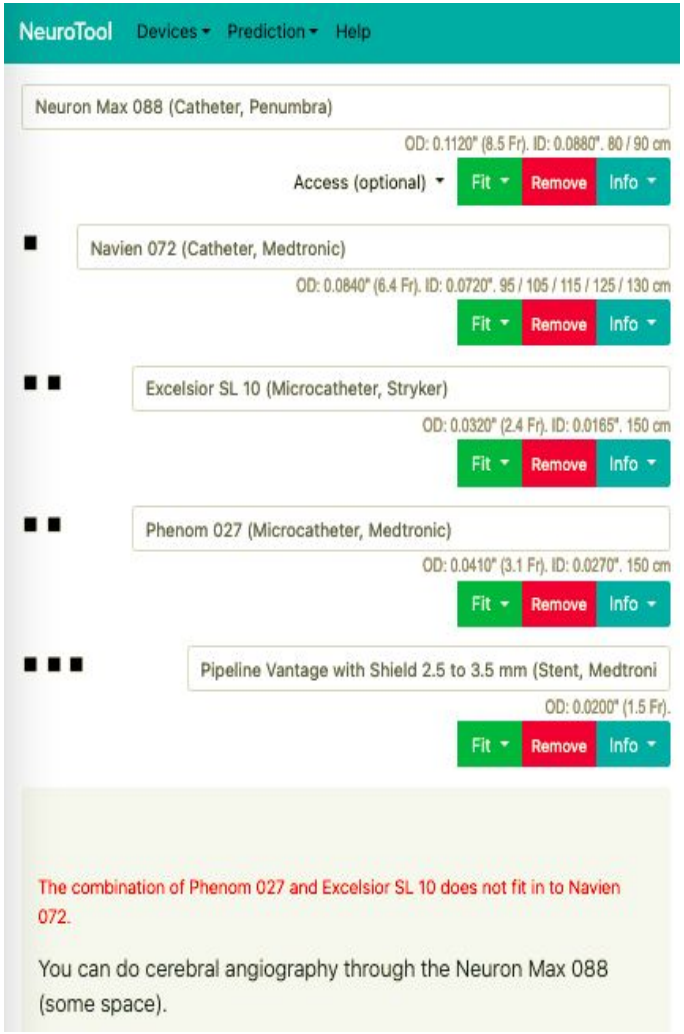
DMSO

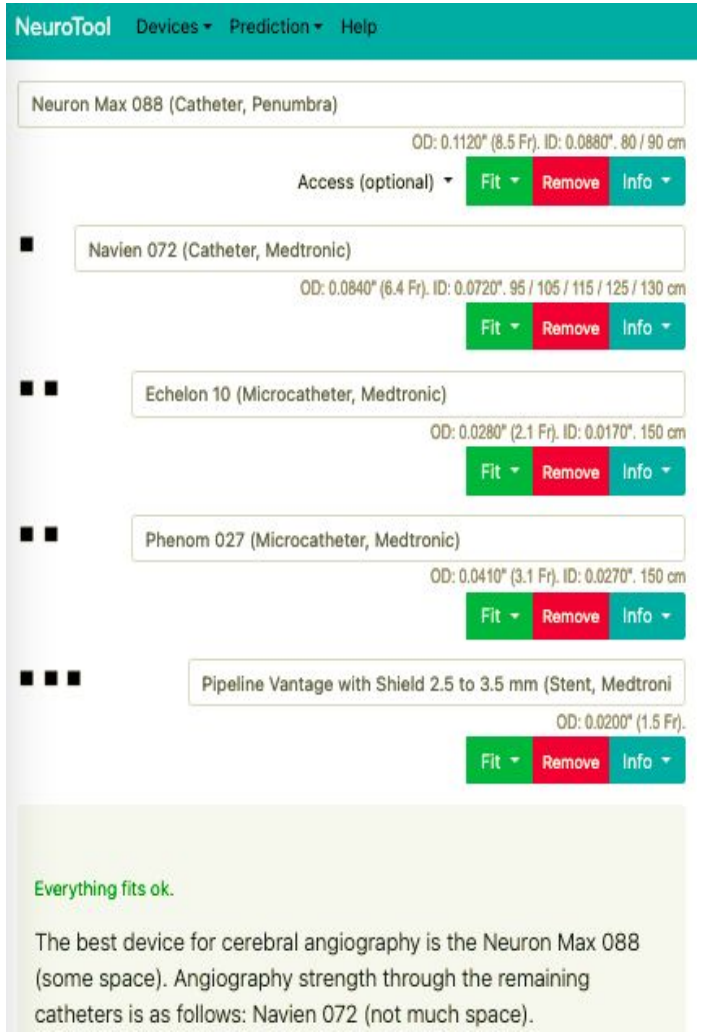
- Finally the database is queried as to whether the devices are **DMSO** compatible



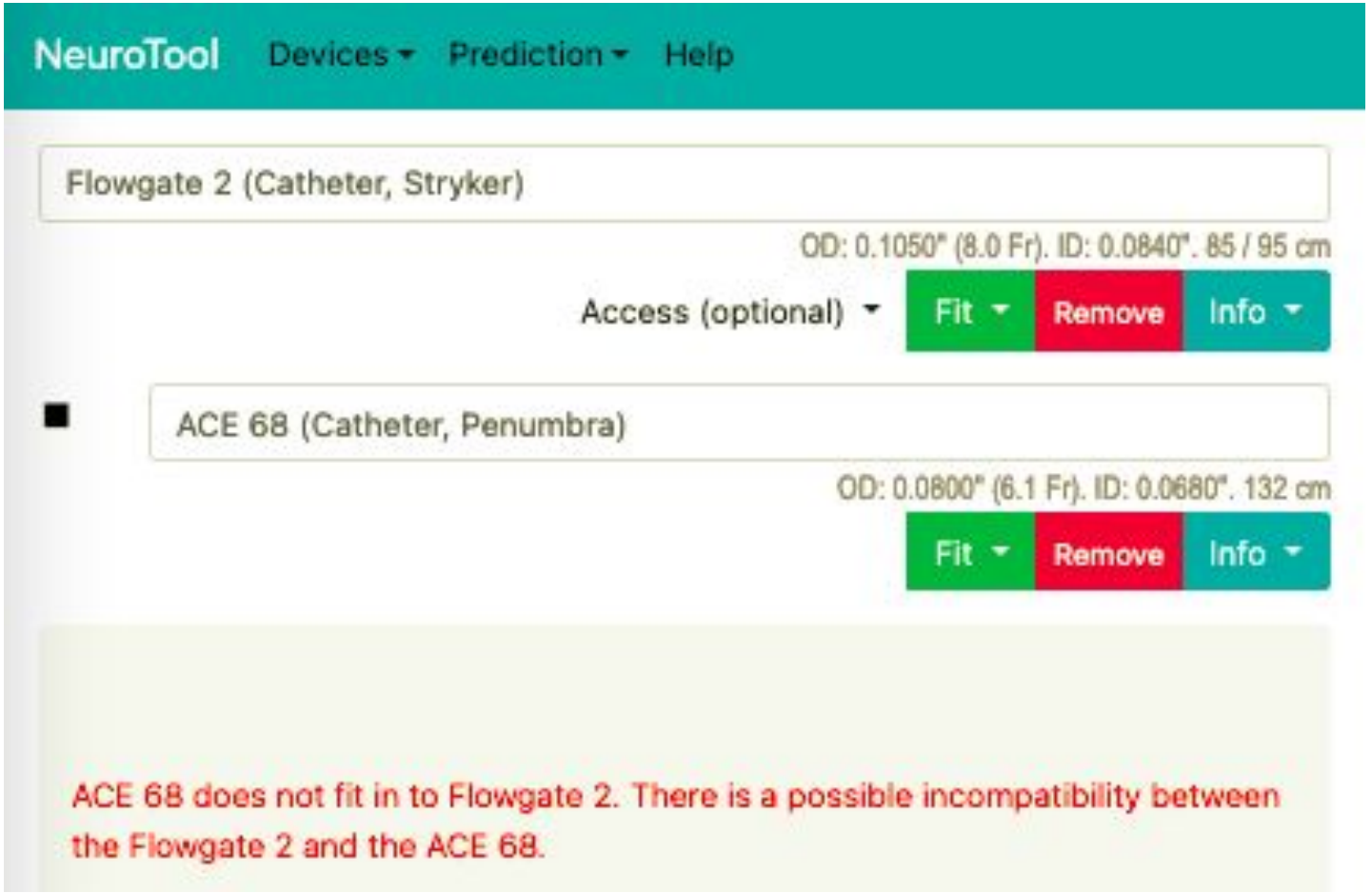


Examples


NeuroTool
Devices
Prediction
Help
Neuron Max 088 (Catheter, Penumbra)
OD: 0.1120" (8.5 Fr). ID: 0.0880". 80 / 90 cm
Access (optional)
Fit
Remove
Info
Navien 072 (Catheter, Medtronic)
OD: 0.0840" (6.4 Fr). ID: 0.0720". 95 / 105 / 115 / 125 / 130 cm
Excelsior SL 10 (Microcatheter, Stryker)
OD: 0.0320" (2.4 Fr). ID: 0.0165". 150 cm
Phenom 027 (Microcatheter, Medtronic)
OD: 0.0410" (3.1 Fr). ID: 0.0270". 150 cm
Pipeline Vantage with Shield 2.5 to 3.5 mm (Stent, Medtroni
OD: 0.0200" (1.5 Fr).
The combination of Phenom 027 and Excelsior SL 10 does not fit in to Navien 072.
You can do cerebral angiography through the Neuron Max 088 (some space).

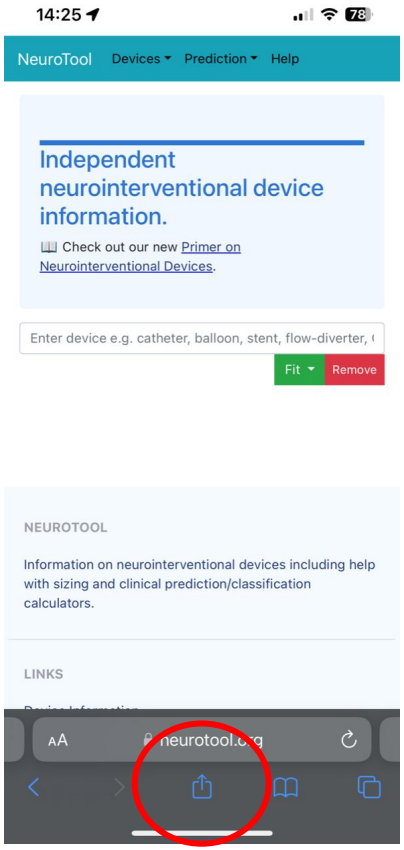

NeuroTool
Devices
Prediction
Help
Neuron Max 088 (Catheter, Penumbra)
OD: 0.1120" (8.5 Fr). ID: 0.0880". 80 / 90 cm
Access (optional)
Fit
Remove
Info
Navien 072 (Catheter, Medtronic)
OD: 0.0840" (6.4 Fr). ID: 0.0720". 95 / 105 / 115 / 125 / 130 cm
Echelon 10 (Microcatheter, Medtronic)
OD: 0.0280" (2.1 Fr). ID: 0.0170". 150 cm
Phenom 027 (Microcatheter, Medtronic)
OD: 0.0410" (3.1 Fr). ID: 0.0270". 150 cm
Pipeline Vantage with Shield 2.5 to 3.5 mm (Stent, Medtroni
OD: 0.0200" (1.5 Fr).
Everything fits ok.
The best device for cerebral angiography is the Neuron Max 088 (some space). Angiography strength through the remaining catheters is as follows: Navien 072 (not much space).

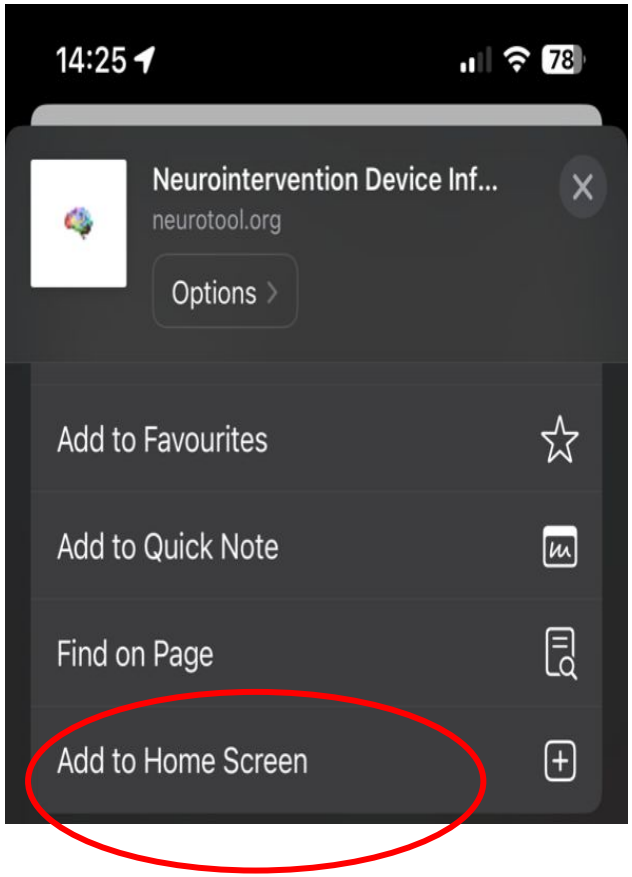
Examples


NeuroTool
Devices
Prediction
Help
Flowgate 2 (Catheter, Stryker)
OD: 0.1050" (8.0 Fr). ID: 0.0840". 85 / 95 cm
Access (optional)
Fit
Remove
Info
ACE 68 (Catheter, Penumbra)
OD: 0.0800" (6.1 Fr). ID: 0.0680". 132 cm
Fit
Remove
Info
ACE 68 does not fit in to Flowgate 2. There is a possible incompatibility between the Flowgate 2 and the ACE 68.

Offline usage

- On iPhones the app can be saved on to the homescreen for offline usage.





Conclusions

- A tool was developed to aid in decisions regarding device:
  - **sizing,**
  - **ease of angiography, and**
  - **liquid embolic compatibility.**
- This is currently the **only** model that can accurately predict whether 3 or more devices will fit inside the single lumen of a larger device.
- The tool and source code are freely available at www.neurotool.org