Technical Note & Surgical Technique

Pentaxial access platform for ultra-distal intracranial delivery of a large-bore hyperflexible DIC (distal intracranial catheter): A technical note

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Abstract

Background: Intracranial access techniques in modern neurointervention are shifting towards more robust access platforms. We present in this report a novel method of navigating a 5 French distal intracranial catheter (DIC) deep within the intracranial circulation in an atraumatic fashion via a pentaxial access system.

Methods: We retrospectively reviewed all neurointerventions performed at two author institutions identifying all aneurysm treatments where the pentaxial system was used to build the catheter support for intracranial positioning of a 5 French DIC.

Results: The pentaxial access platform provided ultra-distal intracranial navigation of the 5 French DIC in the following 11 neurointerventions for treatment of anterior circulation aneurysms: Pipeline embolization device (PED) for anterior communicating artery (ACom) aneurysm, n = 2; surpass for large internal carotid artery (ICA) aneurysm, n = 4; Woven EndoBridge (WEB) device for ACom aneurysm, n = 5. Mean patient age was 55 ± 11 years (range 40–75 years). Mean aneurysm size was 6.7 mm ± 3.8 mm (range 2–16 mm). Mean fluoroscopy time was 29 ± 16.7 min. Intra-procedural DIC positions achieved included supraclinoid ICA (n = 6), M1 (n = 4), and A1 (n = 1). No significant catheter-related complications occurred.

Conclusion: Distal intracranial catheters can achieve ultra-distal intracranial positions safely with the pentaxial access platform. This technique is a near no step-off, atraumatic method of navigating a DIC in a stepwise fashion over de-escalating smaller diameter catheters via a microwire. Familiarity with catheter specifications including diameters and length is essential for the success of this system.

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1. Introduction

The flow diversion revolution has not only changed the management of intracranial aneurysms from an approach of endovascular occlusion to endoluminal reconstruction, it has also transformed the access techniques of neurointerventional procedures towards more robust access platforms. Catheter support systems have shifted from a classic biaxial set-up to a more sturdy triaxial system. This is secondary to the comparatively larger size of delivery systems required for modern neuroendovascular devices, first with the Pipeline embolization device (PED; Medtronic Neurovascular, Irvine, CA) and more recently with the Woven EndoBridge Device (WEB; Sequent Medical, Aliso Viejo, CA) and the Surpass flow diverter (Stryker Neurovascular, Freemont, CA).

Distal intracranial catheters (DICs), such as the Navien DIC (Medtronic Neurovascular, Irvine, CA) and DAC (Distal Access Catheter; Stryker Neurovascular, Freemont, CA), serve as the cornerstones of flexible soft tips allowing for trackability into intracranial locations. Several neurointerventional centers have described their experiences with delivering these catheters in various intracranial positions [1–6]. In cases of tortuous anatomy, a few strategies have also been described using a balloon or the Merci device as anchors to navigate the DICs into...
the desired intracranial position [7,8]. We present in this report a novel technique of navigating a 5 French DIC deep within the intracranial circulation in a near no step-off fashion via a pentaxial access system during neurointervention.

2. Patients and methods

2.1. Patient selection

We retrospectively reviewed all neurointerventions performed at two author institutions, identifying all aneurysm treatments where the pentaxial system was used to build the catheter access for the intracranial positioning of a 5 French DIC.

2.2. Data collection

Data on patient demographics, aneurysm characteristics, proximal tortuosity, use of vasodilator, procedural equipment, and technical details including final intra-procedural 5 French DIC position, and peri-procedural complications related to the catheter position were collected. Factors assessed for proximal tortuosity included aortic arch type, cervical ICA tortuosity (defined as a 90° turn, hairpin turn, or corkscrew loop), and cavernous ICA grade [9]. Data were presented as counts.

2.3. Pentaxial access technique

All patients were treated preoperatively with a dual antiplatelet regimen consisting of aspirin 325 mg daily and clopidogrel 75 mg daily for at least 7 days prior to the intervention. All procedures were performed with systemic anticoagulation using heparin with a 5000-unit bolus at the start of each case followed by an intra-procedure rebolus of 1000 units at each additional hour.

The pentaxial system was used through femoral access. The system consisted of a 10 cm 8 French Pinnacle Sheath (Terumo Medical Corporation, Somerset, NJ), 6 French 0.088” inner diameter (ID) Neuron Max guide sheath catheter (Penumbra, Alameda, CA), a 5 French 0.058” ID Navien DIC, a 0.038” ID DAC, and 0.021” ID Prowler Select Plus 45° catheter (Codman Neurovascular, Raynham, MA) with a Fathom 16 microwire (Boston Scientific, Marlborough, MA). In the last 2 cases performed for WEB embolization, the 0.021” ID VIA catheter (Sequent Medical, Aliso Viejo, CA) was used instead of the Prowler Select Plus. Table 1 presents the complete specifications of the equipment used for this pentaxial access system.

After placement of the 10 cm 8 F femoral sheath, the 6 F 0.088” Neuron Max guide sheath was coaxially introduced with a 6.5 F Shuttle Select Slip-Cath Selective Catheter (Cook Medical, Bloomington, IN) and positioned within the common carotid or proximal internal carotid artery over a 0.035” glidewire (Terumo Medical Corporation, Somerset, NJ). The slip-cath and glideewire were then removed. Thereafter, small doses of intra-arterial verapamil (typically 5 mg) were infused through the Neuromax sheath prophylactically to prevent catheter-induced vasospasm in some cases. Once the Neuromax Max was in position, the Navien DIC, DAC and 0.021” catheter (Prowler Select Plus or Via) were introduced as a unit with the Fathom 16 microwire. The Navien DIC was then advanced to the desired distal intracranial position by first navigating the Fathom 16 microwire, followed by the 0.021” catheter over the microwire, then tracking the DAC over the 0.021” catheter, and finally tracking the Navien DIC over the DAC. This sequence was repeated in a stepwise fashion until the Navien reached its final intracranial position. After achieving the desired Navien DIC position, the DAC, 0.021” catheter and Fathom microwire were removed as a unit. A contrast injection was then performed to verify preserved antegrade flow and to assess for parent artery injury or catheter-induced vasospasm. Aneurysm embolization then proceeded with the respective devices. After completion of the aneurysm embolization, final control cerebral angiography with visualization of the catheterized parent artery was performed.

3. Results

The pentaxial access system was used for the ultra-distal intracranial positioning of the 5 F Navien DIC in 11 neuroendovascular treatments of anterior circulation aneurysms. Table 2 summarizes the details of the cases. Three men and 8 women were treated (aged 40 to 75 years, mean 55 ± 11 years). Mean aneurysm size was 6.7 mm ± 3.8 mm (range 2 to 16 mm). Five patients, each with anterior communicating artery (ACom) aneurysms, underwent WEB embolization. Four patients with large internal carotid artery (ICA) aneurysms were treated with the Surpass flow diverter and 2 patients with ACom aneurysms were treated with the PED (one with classic, the other with Flex). Arch types were type I (n = 5), type II (n = 2), type III (n = 0), undocument ed (n = 4). Two patients had cervical ICA tortuosity, defined as a 90° turn, hairpin turn, or corkscrew loop. There was a spectrum of cavernous ICA tortuosity: type IA (n = 2), type IB (n = 3), type II (n = 5), type III (n = 0), type IV (n = 1). In 9 of the 11 cases, prophylactic vasodilator was administered prior to positioning of the DIC for catheter-induced vasospasm prophylaxis.

The pentaxial access technique for distal intracranial positioning of the DIC was successful in all cases on the initial attempt. Final intracranial DIC positions included supraclinoid ICA (n = 6), M1 segment of the middle cerebral artery (MCA, n = 4) and A1 segment of the anterior cerebral artery (ACA, n = 1). Mean fluoroscopy time was 29 ± 16.7 min and mean systemic heparin dose was 5100 ± 1900 units. No parent artery dissections or significant catheter induced vasospasm was observed in any of the cases. Additionally, none of the cases required retraction of the DIC as a result of poor distal antegrade flow related to catheter-induced arterial spasm. All aneurysm embolizations were completed successfully except for one WEB embolization secondary to aneurysm morphology.

Table 1

Pentaxial access platform – catheter specifications.

<table>
<thead>
<tr>
<th>Catheter</th>
<th>ID</th>
<th>Length (cm)</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 8 F Pinnacle Sheath</td>
<td>8 F</td>
<td>10</td>
<td>Terumo</td>
</tr>
<tr>
<td>2 Neuron Max</td>
<td>8 F 0.088 in.</td>
<td>90</td>
<td>Penumbra</td>
</tr>
<tr>
<td>3 5 F Navien DIC</td>
<td>5 F 0.070 in.</td>
<td>115</td>
<td>Medtronic Neurovascular</td>
</tr>
<tr>
<td>4 3.9 F DAC</td>
<td>2.9 F 0.038 in.</td>
<td>136</td>
<td>Stryker</td>
</tr>
<tr>
<td></td>
<td>(1.3 mm)</td>
<td></td>
<td>Neurovascular</td>
</tr>
<tr>
<td>5 Prowler Select Plus</td>
<td>2.8 Fr (0.037 in., 0.95 mm)</td>
<td>161</td>
<td>Codman Neurovascular</td>
</tr>
<tr>
<td>45°</td>
<td>0.021 in. (0.53 mm)</td>
<td>500</td>
<td>Sequent Medical</td>
</tr>
<tr>
<td>VIA 21°</td>
<td>2.8 Fr (0.037 in., 0.9 mm)</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.021 in. (0.5 mm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: DAC = distal access catheter; DIC = distal intracranial catheter; F = French; ID = inner diameter; OD = outer diameter.

* 0.021” VIA catheter used in 2 cases.
3.1. Case examples

3.1.1. Case illustration 1

A quadragenarian patient with residual bilobed 15 mm ophthalmic aneurysm that was previously ruptured and treated with balloon-assisted coiling presented for treatment with the Surpass flow diverter. Fig. 1 demonstrates the aneurysm, the workhorses of the pentaxial access system (the 0.038″ DAC with the 0.021″ Prowler Select Plus and Fathom 16 microwire), and highlights the sequence of Surpass deployment. The 5 F Navien DIC was navigated up to the M1 segment of the MCA via the pentaxial system. Once the final position of the Navien DIC was achieved in the M1 segment, the DAC with the 0.021″ catheter and microwire were removed as a unit. A Surpass sized 3 × 25 mm was then introduced and the Navien DIC was withdrawn to the ICA to allow for the device deployment.

Table 2
Patient and procedural details.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>ANR size (mm)</th>
<th>Aneurysm location</th>
<th>Arch type</th>
<th>Cerv ICA tortuosity</th>
<th>cICA grade</th>
<th>Treatment procedure</th>
<th>IA verapamil (mg)</th>
<th>Fluoro time (min)</th>
<th>Heparin (units)</th>
<th>Navien position</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70s</td>
<td>9.4</td>
<td>ACom</td>
<td>I</td>
<td>Y</td>
<td>II</td>
<td>WEB</td>
<td>5</td>
<td>36.4</td>
<td>7000</td>
<td>sICA</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>50s</td>
<td>3.8 (6.4b)</td>
<td>Recur Coiled</td>
<td>II</td>
<td>N</td>
<td>IV</td>
<td>PED</td>
<td>5</td>
<td>38.1</td>
<td>5000</td>
<td>sICA</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>50s</td>
<td>6.2</td>
<td>ACom</td>
<td>I</td>
<td>Y</td>
<td>IA</td>
<td>FLEX</td>
<td>N</td>
<td>21.2</td>
<td>6000</td>
<td>sICA</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>40s</td>
<td>6 (15c)</td>
<td>Residual Coiled Ophthalmic</td>
<td>–</td>
<td>N</td>
<td>IB</td>
<td>Surpass</td>
<td>5</td>
<td>22.3</td>
<td>6000</td>
<td>M1</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>40s</td>
<td>5</td>
<td>ACom</td>
<td>–</td>
<td>N</td>
<td>IB</td>
<td>WEB</td>
<td>5</td>
<td>30.5</td>
<td>0 (SAH) A1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>50s</td>
<td>5</td>
<td>ACom</td>
<td>–</td>
<td>N</td>
<td>II</td>
<td>WEB</td>
<td>5</td>
<td>74.8</td>
<td>6000</td>
<td>sICA</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>60s</td>
<td>16</td>
<td>Horizontal Cavernous</td>
<td>I</td>
<td>N</td>
<td>II</td>
<td>Surpass</td>
<td>5</td>
<td>18.6</td>
<td>6000</td>
<td>M1</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>40s</td>
<td>11 (22d)</td>
<td>Recur Clipped Ophthalmic</td>
<td>I</td>
<td>N</td>
<td>IB</td>
<td>Surpass</td>
<td>N</td>
<td>21.1</td>
<td>6000</td>
<td>M1</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>50s</td>
<td>5.5 (16e)</td>
<td>Recur Coiled Supraclinoid</td>
<td>I</td>
<td>N</td>
<td>II</td>
<td>Surpass</td>
<td>5</td>
<td>18.1</td>
<td>6000</td>
<td>M1</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>70s</td>
<td>6</td>
<td>ACom</td>
<td>II</td>
<td>N</td>
<td>IA</td>
<td>WEF</td>
<td>5</td>
<td>19.5</td>
<td>4000</td>
<td>sICA</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>50s</td>
<td>4.7</td>
<td>ACom</td>
<td>–</td>
<td>N</td>
<td>II</td>
<td>WEF</td>
<td>5</td>
<td>19.8</td>
<td>4000</td>
<td>sICA</td>
<td>None</td>
</tr>
</tbody>
</table>

Abbreviations: ACom = anterior communicating artery; ANR = aneurysm; FLEX = 2nd generation PED; IA = intra-arterial; PED = Pipeline embolization device; sICA = supraclinoid ICA; SAH = subarachnoid hemorrhage; WEB = Woven EndoBridge device.

a cICA grade = cavernous ICA tortuosity classification system as previously described [9].

b Original aneurysm size.

c 0.021″ VIA catheter.

d 0.038″ DAC with the 0.021″ Prowler Select Plus and Fathom 16 microwire.

e Navigation of 5 F Navien DIC to the M1 segment via pentaxial access platform for Surpass deployment of previously coiled residual bilobed ophthalmic aneurysm. (A) Right common carotid, AP view, of the proximal cervical ICA. (B) Right internal carotid 3-dimensional reconstruction and (C) right common carotid DSA, lateral view, demonstrating the previously ruptured bilobed ophthalmic aneurysm with residual filling. (D) Photograph of the workhorses in the pentaxial system: black arrow = 5 F Navien DIC, single white arrowhead = 0.038″ DAC, double white arrowhead = 0.021″ Prowler Select Plus, lime green torque = Fathom 16 microwire. (E–G) Intra-procedural native single-shot fluoroscopy AP views of Surpass deployment. Black arrow = tip of Navien, white arrow = Surpass microcatheter tip, black arrowhead = distal end of Surpass device. (H, I) Final control DSA, lateral view, demonstrates significant contrast stasis in the aneurysm marked by the asterisk.

Fig. 1.
3.1.2. Case illustration 2

A quadragenarian patient presented with grade 1 subarachnoid hemorrhage from rupture of a 5 mm left filling ACom aneurysm. The case is illustrated in detail in Fig. 2 and Videos 1a and 1b (available online only). Using the pentaxial platform, the 5 F Navien DIC was navigated up to the A1 segment of the ACA. Videos 1a and 1b demonstrates the stepwise advancement of the 0.021″ Prowler Select Plus microcatheter over the Fathom 16 microwire, the 0.038″ DAC over the Prowler Select Plus, the 5 F Navien DIC over the DAC, and the Neuron Max over the Navien DIC, which provided additional proximal support to allow further navigation of the Navien DIC into the A1 segment. Once the final position of the Navien DIC in the A1 segment was achieved, the DAC with the 0.021″ catheter and microwire were removed as a unit. The 0.027″ VIA catheter was then introduced into the Navien for the aneurysm access and subsequent WEB deployment.

4. Discussion

We present in this report a novel access technique for navigating a 5 French DIC into ultra-distal intracranial position atraumatically via a pentaxial access platform. This method was used successfully in all 11 neurointerventions presented for the treatment of anterior circulation aneurysms. In 5 of these cases, the DIC was navigated beyond the distal ICA into final positions within the ACA 1 segment of the middle cerebral artery and A1 segment of the anterior cerebral artery. The ultra-distal intracranial navigation of the 5 French DIC using the pentaxial access platform was achievable without any significant catheter-related injuries to the parent vessel or flow-limiting vasospasm.

The development of modern neuroendovascular devices that require larger (0.027″ inner diameter) delivery microcatheters, such as flow diverters and intrasaccular devices, has propagated advances in catheter technology to provide robust distal intracranial support. Newer access catheters, the DICs, have a hybrid design of soft, nitinol-wound flexible mid-sections and distal tips that rely upon the proximal stability of a guide sheath, such as a Neuron Max, to allow for intracranial positioning. The Navien and DAC are examples of these catheters that are now routinely positioned above the skull base for various types of neurointerventions [1-6]. Several authors have described the safety of intracranial positioning with these catheters utilizing the triaxial system that consists of a guide sheath catheter, DIC, and microcatheter with microwire [2-6]. Compared to traditional biaxial approaches, the triaxial system provides a stable platform for one-to-one microcatheter movement in intracranial locations, allowing for improved microcatheter feedback and enhanced procedural safety.

Alternative strategies to the triaxial system for navigating a DIC intracranially have been described in the treatment of acute ischemic stroke. In cases of a tortuous ophthalmic segment of the ICA, Hui et al. used a Merci retriever deployed at the M1 segment of the MCA as an anchor to straighten the ophthalmic segment in order to advance the aspiration catheter to the target occlusion site [7]. Although the authors reported the success of this method in 3 cases, they also noted the inherent risks of using the Merci device in this manner, such as arterial intimal damage, dissection, rupture or device fracture.

In another publication, Peeling and Fiorella described a similar technique of intracranial access catheter positioning using a hypercompliant balloon instead as an anchor to navigate through the tortuous segment created less stress on the vessel wall than the traditional...
0.035" glidewire method and subsequently was less likely to create traumatic injury or vasospasm. They conceded, however, that the drawback of this balloon-anchoring technique was the need for temporary balloon occlusion of the parent ICA.

The pentaxial access technique described in this report allows for distal intracranial positioning of a 5 French DIC in a stepwiseatraumatic approach without needing an adjunctive device as seen in the other two methods discussed above [7,8]. This technique was born from our early observations of the 5 French DIC advantages in Surpass flow diverter neurointerventions [10]. Similar to our approach in PED flow diversion [11–13], for the Surpass cases we routinely establish a triaxial access platform consisting of a 6 French guide sheath and a 5 French DIC, such as the Navien. We previously described a strategy for positioning the Navien DIC in these Surpass cases called the “climbing” technique whereby the 5 French Navien DIC is advanced over the Surpass delivery system in a stepwise fashion until a distal position of the DIC is obtained. We discovered the advantage of this technique is the slip-tip relationship of the Surpass delivery system within the Navien. The delivery system for the Surpass flow diverter consists of a Surpass delivery microcatheter with 0.040" ID (3.6–3.7 French outer diameter) and 0.016" ID pusher catheter [10]. When the Surpass delivery system is coaxially in the 5 French 0.058" Navien DIC, no step-off is evident, which allows for smooth tracking of the DIC over the Surpass delivery system, even in cases with proximal tortuosity. This climbing technique is also used to establish endoluminal device access with the Navien DIC after the Surpass device has been completely deployed in preparation for either device postprocessing or for telescoping a second device if necessary. At this point, the pusher is first advanced over the 0.014" microwire, the Surpass delivery microcatheter is then advanced over the pusher to an endoluminal position and the Navien DIC is finally advanced over the microcatheter into the proximal end of the deployed Surpass device. This strategy has consistently allowed us to establish endoluminal access with the 5 French Navien DIC post Surpass deployment in most of the Surpass cases performed.

We adapted the 5 French Navien DIC “climbing” technique from the Surpass experience to establish the pentaxial access platform for navigating a 5 French DIC intracranially in an atraumatic, no step-off fashion for any neurointervention. The slip-tip nature of the Surpass delivery system coaxially within the Navien was reproduced with the combination of a 0.021" catheter within a 0.038" DAC within the 5 French 0.058" Navien DIC. In lieu of the Surpass delivery system with the 0.040" ID Surpass delivery microcatheter and the 0.016" ID pusher catheter, the 0.038" DAC and the 0.021" catheter (either Prowler Select Plus 45° or VIA catheter) with a Fathom 16 microwire were the workhorses in the pentaxial platform described in this report. Compared to traditional 0.035" glidewire or triaxial techniques for intracranial guidecatheter access, this pentaxial strategy for DIC navigation is a less traumatic method of establishing intracranial catheter position by allowing the stepwise advancement of larger diameter support catheters over descalating smaller diameter microcatheters in a near no-step-off manner over a microwire. As noted previously by Peeling and Fiorella, the microwire-microcatheter navigation is particularly advantageous in tortuous vascularity where the microwire is gentler on the vessel wall. The stepwise catheter-size tapering of the pentaxial system also allows the microwire and (micro)catheters to maintain a center position within the vessel lumen rather than veering to the outer or inner curvatures. This prevents inadvertent buckling of the catheters as well as catheter-induced vasospasm during the stepwise tracking process of each catheter and preserves the native ICA anatomy throughout the DIC positioning. In this report, we were able to safely and atraumatically (no dissections observed) navigate the 5 French Navien DIC into ultra-distal intracranial locations beyond the ICA using this pentaxial system.

The pentaxial access technique for establishing intracranial DIC positioning does require handling multiple catheters and heparinized saline flush lines. Some neurointerventionalists may raise this as a concern for added procedural complexity. However, in our experience, the extra time needed to prepare this system is minimal, particularly with more experience using this technique. Additionally, the efficiency in DIC positioning and the stability achieved with this approach are advantages that outweigh the perceived time lost in setting up the catheters and flush lines. More important in the preparation of the pentaxial platform is familiarity with the lengths and diameters (bolder inner and outer) of each catheter. The specifications of the catheters used in the pentaxial system are shown in Table 1. Additional attention also needs to be paid to rotational hemostatic valve (RHV) length given that the RHV may reduce the working catheter length. In all cases presented in this report, we used Check-Flo (Cook Medical, Bloomington, IN) instead of RHVs on the 5 French DIC, and the 0.038" DAC in the pentaxial system. Once the DIC was navigated to the desired intracranial location and the DAC with the 0.021" catheter and microwire were removed from the DIC, the Check-Flo on the DIC was then changed to a RHV for better catheter control throughout the remainder of the case.

5. Conclusion

Robust intracranial access platforms are becoming essential for the safe delivery of modern neuroendovascular devices. DICS are a newer class of hybrid distal access catheters developed to meet this need for intracranial catheter support. Concern for catheter-induced arterial injury and proximal tortuosity limit the performance applicability of DICS. The pentaxial access platform provides a safe and atraumatic approach for navigating the DIC into desired intracranial locations. This strategy may be used to overcome limitations of proximal tortuosity and may also be used to establish DIC support in ultra-distal intracranial locations. Familiarity with catheter specifications is critical to the success of the pentaxial access platform.

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Contributorship statement

LML drafted the manuscript and critically revised the manuscript for important intellectual content. GPC assisted in critically revising the manuscript. RRI assisted in critically revising the manuscript. BJ assisted with the data collection and analysis. ALC conceived of the manuscript and critically reviewed the important intellectual content. All authors read and approved the final manuscript.

Data sharing statement

There is no additional unpublished data from this study.

Patient consent

All individual identifying information, including age and sex, have been meticulous anonymised to achieve appropriate anonymity in the manuscript.

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