Use of the advanced triple coaxial microcatheter system in superselective arterial embolisation for complex interventional cases: an initial experience with the system.

Sonam Tashi
Singapore General Hospital

Zehao Tan (✉ tan.zehao@singhealth.com.sg)
Singapore General Hospital  https://orcid.org/0000-0002-7019-5814

Apoorva Gogna
Singapore General Hospital

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Abstract

Learning objective:

To share our experience in utilizing the triple coaxial (triaxial) system in super-selective cannulation of arteries for complex embolisation procedures.

Background:

Percutaneous transcatheter selective embolisation is a widely performed for a myriad of oncologic (e.g. trans-arterial chemo- or radio-embolization) and non-oncologic (e.g. for embolization of bleeding and benign conditions such as uterine fibroid and benign prostate hyperplasia) purposes.

The cornerstone of such embolisation procedures is to achieve super-selective cannulation of the arterial supply to the tumour/organ preventing the complication of non-target embolisation. However, the presence of tortuous and complex vascular anatomy can pose a major challenge for achieving this goal.

Clinical findings/procedural details:

The triaxial system utilizes 2 smaller microcatheter telescoped through each other and over a microwire within an angiographic catheter. We have adopted the use of the triaxial system due to its perceived superior torquability and trackability compared to the conventional coaxial system for cases which superselective cannulation is challenging. The triaxial system is also favourable in situations which the inner microcatheter needs to “sacrificed” after administering embolics (e.g. after administering radionuclides in radioembolization, N-butyl cyanoacrylate (NBCA) glue or dimethyl-sulfoxide (DMSO)). Through a case series with procedural details such as fluoroscopic time, contrast administered etc, we hope to illustrate the utility and efficacy of the triaxial system as well as present pitfalls in its usage.

Conclusion:

The triaxial system is safe for use in embolization procedures and can confer advantages over conventional co-axial system for specific situations.

Introduction

Percutaneous transcatheter embolisation is a well-established and widely performed minimally invasive therapeutic option for a variety of clinical conditions such as transcatheter arterial chemoembolisation or radioembolisation for hepatocellular carcinoma (HCC), bronchial artery embolisation (BAE) for haemoptysis, prostate artery embolization for benign prostatic hyperplasia (BPH), embolisation for gastrointestinal bleeding, and embolisation of type II endoleaks following endovascular aneurysm repair (1, 2, 3, 4). The goal of embolisation is to occlude or reduce blood or lymph flow in the arterial, venous, or lymphatic system.

One of the key cornerstones of embolisation is superselective catheterisation. This involves advancing the catheter tip within the feeding vessel as close as possible to the target lesion with the goal of delivering the payload / embolic agents to achieve effective embolisation and minimise the risk of non-target vessel embolisation, which may result in disastrous consequences. For example, in the case of BAE, superselective cannulation is performed whilst paying particular attention to the microcatheter tip, which is guided beyond the origin of the anterior medullary arteries or the great anterior radiculomedullary artery (artery of Adamkiewicz) to avoid the dreaded complication of transverse myelitis due to spinal cord ischemia (5).

Although superselective cannulation is an indispensable manoeuvre in performing embolisation, tortuous, narrowed, and complex vascular anatomy can pose a problem for navigating the microcatheters to the actual site of pathology. Vessel tortuosity can result in a lack of pushability of the microcatheters and the loss of guidewire torque essential for the successful cannulation of a vessel. Tortuous vessels may also prevent the all-around transmission of energy over the microcatheter and
occasionally leads to sudden forward motion leading to vessel spasm and injury such as a dissection and/or perforation (6). This can result in complications, failure of the procedure, and longer procedure duration with implications for hospitalisation stay and cost.

In recent years, the immense improvement in microcatheters, guidewires, and digital angiographic equipment and technology have enabled more peripheral superselective catheterisation of distal vessels. And with the availability of an even smaller microcatheter recently, we have adopted this new technique, where a smaller microcatheter is introduced into a larger microcatheter parked inside a large catheter called the triple coaxial (triaxial) system to perform superselective catheterisation and embolisation of various conditions.

**Materials & Methods**

We conducted a retrospective audit of 10 cases at our institute, where the triaxial system was utilised for various complex embolisation cases from 2020 to 2021. Two interventional radiologists (AG and ST) performed the cases with an experience of > 10yrs and > 5yrs, respectively. The recorded procedural details, such as duration of the procedure, amount of contrast media utilised, fluoroscopy time, radiation dose, and procedural success were captured for audit. The procedures were performed using either the Canon Medical Alphenix (Tochigi, Japan) or Siemens Medical Artis (Erlangen, Germany) interventional angiography system and iohexol; Omnipaque 350 (GE Healthcare) as the contrast media. No approval from our institutional review board was necessary for this retrospective anonymised report.

**Devices used in the Triaxial system**

Most embolisation cases involve the introduction of a 4 or 5-Fr. sheath into the common femoral or radial artery using a 4 or 5-Fr. catheter of various configurations depending on the site of the procedure. Conventionally microcatheters usually ranging from 2.0 to 2.9-Fr. are inserted via the 4 or 5-Fr. catheter coaxially for these procedures (Figure. 1).

For the triaxial system, a small microcatheter, a large microcatheter, and a 4 or 5-Fr. catheter is used (Figure. 2). For the small microcatheter, a 1.6-Fr. microcatheter with a 1.6-Fr. distal and 1.8- Fr. proximal diameter (CARNELIAN NT, Tokai Medical Products Inc, Kasugai, Japan) is inserted into a larger 2.7-Fr. microcatheter with a 2.7-Fr. distal and 2.9-Fr. proximal diameter (CARNELIAN, Tokai Medical Products Inc. or PROGREAT, Terumo Medical, Tokyo, Japan) along with a 0.014-inch microguidewire (TRANSEND EX 0.014, Boston Scientific, Marlborough, MA, USA). The larger 2.7-Fr. microcatheters have large inner diameters and are usually deployed for higher quality angiograms as a high rate and volume of contrast media can be injected via these catheters.

**Results**

All procedures were completed with successful embolisation of the target vessel(s). Transfemoral approach was used in all the cases. 6 of 10 cases were hepatic artery embolisation due to the relatively high number of hepatic artery interventions like transarterial chemoembolisation (TACE) and transarterial radioembolisation (TARE) being performed in our institute. The decision to use the triaxial system was based on the operator's experience. If the initial angiogram via the 4 or 5-Fr. catheter demonstrated small calibre tortuous target vessels, where there is perceived difficulty in negotiating these vessels, then the triaxial system was utilised. A range of procedures was performed depending on the location, with an assorted range of parameters obtained (summarised in Table 1).
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Procedure time (min)</th>
<th>Contrast media usage (ml)</th>
<th>Fluoroscopy time (min)</th>
<th>DAP (Gy.cm²)</th>
<th>Reference Fluoroscopy time (min)</th>
<th>Reference DAP (Gy.cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAE</td>
<td>129</td>
<td>140</td>
<td>16.3</td>
<td>84.79</td>
<td>25.7</td>
<td>6.9</td>
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<tr>
<td>Endoleak embolisation (intercoastal artery)</td>
<td>160</td>
<td>55</td>
<td>35.5</td>
<td>190.56</td>
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<td>302.54</td>
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<tr>
<td>Endoleak embolisation (lumbar artery)</td>
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<td>125</td>
<td>39.6</td>
<td>286.41</td>
<td>29.8</td>
<td>302.54</td>
</tr>
<tr>
<td>PAE</td>
<td>130</td>
<td>75</td>
<td>19.5</td>
<td>224.58</td>
<td>30.9</td>
<td>791.73</td>
</tr>
<tr>
<td>TACE</td>
<td>134</td>
<td>140</td>
<td>14.0</td>
<td>171.36</td>
<td>14.8</td>
<td>615.74</td>
</tr>
<tr>
<td>TACE</td>
<td>165</td>
<td>95</td>
<td>18.6</td>
<td>213.10</td>
<td>14.8</td>
<td>615.74</td>
</tr>
<tr>
<td>TACE</td>
<td>109</td>
<td>50</td>
<td>22.3</td>
<td>239.02</td>
<td>14.8</td>
<td>615.74</td>
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<tr>
<td>TACE</td>
<td>198</td>
<td>76</td>
<td>28.0</td>
<td>281.67</td>
<td>14.8</td>
<td>615.74</td>
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<tr>
<td>MAA*</td>
<td>138</td>
<td>87</td>
<td>10.6</td>
<td>121.11</td>
<td>14.8</td>
<td>615.74</td>
</tr>
<tr>
<td>Y-90*</td>
<td>192</td>
<td>95</td>
<td>25.6</td>
<td>271.45</td>
<td>14.8</td>
<td>615.74</td>
</tr>
</tbody>
</table>

*Same reference range for fluoroscopy time and DAP were used for TACE and TARE due to the technical similarities between the two procedures.

**Clinical applications**

**Transarterial chemoembolisation (TACE) for hepatocellular carcinoma (HCC)**

TACE is commonly utilised to treat patients with **Barcelona Clinic Liver Cancer (BCLC) intermediate stage (B)** HCC who are not eligible for curative surgery or percutaneous ablation.

Ultrasound TACE is preferable to nonselective TACE because a selective approach increases the effectiveness of treatment on tumours while reducing the damage and toxicity to the adjacent normal tumour-free liver (7). Therefore, manoeuvring and advancing the microcatheter tip within the feeding artery as close as possible to the tumour is an indispensable step in performing ultraselective TACE, albeit sometimes difficult due to the inherent tortuosity of these arteries commonly found in cirrhotic livers (Figure 3). Particularly in tortuous vascular anatomy, the progression of a microcatheter over the guidewire (conventional coaxial technique) may be difficult or impossible due to the retrograde kickback (bascule) of the guidewire and/or the microcatheter outside the target vessel. Therefore using a triaxial platform in performing ultra-selective TACE would be more useful (1, 8) for achieving higher local control rates for HCC.

**Transarterial radioembolisation (TARE) for hepatocellular carcinoma (HCC)**

Transarterial radioembolisation with yttrium-90 (Y-90) microspheres is an established treatment for unresectable or advanced HCC, where the patient has a large tumour burden or lobar portal vein thrombosis. When radioembolisation is performed using
a lobar approach, patients may be at risk of hepatotoxicity, especially as most of these patients have some degree of underlying existing hepatic dysfunction. Like the concept of ultraselective TACE, superselective radioembolisation can reduce the damage and toxicity to the adjacent normal tumour-free hepatic parenchyma, and the dose can be delivered significantly increased, potentially yielding better response rates without compromising the patient's safety (9). Most, if not all, of these patients, have cirrhotic livers with inherently tortuous arteries, and with the growing demand for superselective catheterisation during TARE, an interventionist can deploy the triaxial system when faced with such challenging anatomy (Figure. 4).

**Bronchial artery embolisation (BAE) for haemoptysis**

BAE is a well-established interventional procedure for managing haemoptysis with an immediate clinical success rate in controlling haemoptysis up to 90% (10).

One of the most severe and dreaded complications is inadvertent embolisation of a spinal artery leading to spinal cord ischaemia and paralysis. The incidence of spinal artery ischaemia from BAE is between 0.6% and 4.4% (11). Hence superselective catheterisation distal to the spinal artery feeder is critical in BAE to minimise the risk of spinal ischaemia. Conversely, vessel tortuosity is a common angiographic finding with a pathological bronchial artery or non-bronchial systemic arteries (12), creating a potential obstacle for navigating the microcatheter for superselective catheterisation (Figure. 5). Woo et al. (13) reported technical failures in 17 out of 293 cases (5.8%), of which the following difficulties were associated with the target artery: tortuosity of the pathological artery in 13 cases, orifice stenosis in 2 cases, a small calibre in 1 case and an acute angle of branching in 1 case. A triaxial system would have been able to overcome these technical challenges.

Studies have also shown that BAE performed with n-butyl cyanoacrylate (NBCA) / glue provides a higher haemoptysis-free survival rate than the more commonly used polyvinyl alcohol (PVA) particles without increasing complication rates in patients with bronchiectasis due to its more durable embolic effect than PVA particles. However, NBCA is known for its difficulties when handling as the catheter tip may adhere to the vessel wall due to its rapid rate of hardening (polymerisation). Hence the microcatheter needs to be rapidly withdrawn after embolisation to prevent this issue. With the triaxial system, access to the feeding artery is still maintained with a 2.7-Fr. microcatheter, so even if the first embolisation attempt was inadequate, the smaller microcatheter could easily be introduced again into the target vessel without losing access. Additionally, NBCA casts sometimes adhere to the microcatheter tip when removing the microcatheter. In the conventional coaxial system, this situation may result in migration of the cast to the aorta or the spinal artery leading to non-target embolisation and potentially serious complications. However, with the triaxial system, the 2.7-Fr. microcatheter can scrape the cast off the smaller microcatheter within the bronchial artery, and the cast can then be carried or flushed away to a safe distal site (3).

**Embolisation of Type II Endoleak after Endovascular Aneurysm Repair (EVAR)**

After EVAR, transcatheter arterial embolisation is a standard treatment option for persistent type II endoleak. Jones et al. (14) reported late aortic rupture in about 6% of patients with persistent type II endoleak, with or without associated aneurysm enlargement.

Type II endoleak is the most common type of endoleak. It is related to the retrograde flow via collaterals arteries, namely the inferior mesenteric artery (IMA), lumbar arteries, and branches of the internal iliac artery. These collaterals can be tortuous and long, making it technically challenging to perform selective catheterisation and embolisation.

With the triaxial system, the 2.7-Fr. intermediate microcatheter supports the smaller inner microcatheter and prevents it from sagging or jumping in cases where the vessels are tortuous, and the interval between the access and treatment sites is pretty distant. Depending on the operator's choice, liquid embolic agents such as NBCA / glue or Onyx (ethylene-vinyl alcohol copolymer with dimethyl sulfoxide solvent and micronized tantalum powder) are occasionally used for the embolisation of the type II endoleaks requiring multiple doses. Access to the feeding artery can still be maintained via the 2.7-Fr. microcatheter, even if the smaller microcatheter has to be replaced, saving on procedure time and radiation (4).
Prostate artery embolisation (PAE) for benign prostatic hyperplasia (BPH)

Prostatic arterial embolisation (PAE) is a safe and effective treatment option for lower urinary tract symptoms caused by BPH. It has a high technical success rate with improved urinary flow rates and quality of life (15). The “PErFecTED” (Proximal Embolisation First, Then Embolise Distal) technique described by Carnevale FC et al. in 2014, where the prostate artery is embolised proximally first, and then the microcatheter is advanced distally into the intraprostatic parenchyma branches for embolisation has shown more significant prostatic ischemia and infarction with clinical improvement of lower urinary symptoms and lower recurrence rates (16).

However, PAE can be technically challenging, especially given that the general age group of these patients is more advanced with concurrent medical conditions leading to tortuous arterial anatomy. Additionally, the prostatic arteries often stem at an acute angle and exhibit atherosclerotic narrowing. Moreover, the degree of atherosclerotic narrowing is significantly correlated with the BPH symptoms, such that the most symptomatic patients may have the most challenging arterial anatomy (17). When faced with a tortuous and narrowed prostatic artery with angulated origins, the triaxial system may prove more advantageous than the conventional system, given its greater ability to negotiate such anatomy to attain the PErFecTED technique.

Discussion

Anecdotal observations in interventional radiology suggest that complex vascular anatomy compounded by increased tortuosity and luminal narrowing correlates with extended procedure time, which translates to longer fluoroscopy time (higher radiation doses) and greater demand for contrast agents with higher risks of technical failure.

A microcatheter catheter system that provides better stability, torquability, and trackability are pivotal to increasing the technical success rate in endovascular interventions. With the triaxial system, the 2.7-Fr. microcatheter as an intermediate catheter provides more stability in the system's position and prevents the microcatheter's springing forward or sagging when faced with a tortuous and challenging vascular anatomy.

Our experiences with these cases demonstrate the superiority of the triaxial system over the conventional coaxial system when faced with small tortuous vessels. Besides providing a more stable platform for embolisation, we can avoid spasms and vascular injury due to repetitive manipulation of the microcatheter resulting in failure of catheterisation (or the procedure). This system also provides certain advantages when liquid embolic agents such as NBCA or Onyx are utilized, as in BAE and the embolisation of type II endoleaks. Especially in the case of NBCA, due to its faster polymerisation rate, the operator needs to quickly withdraw the microcatheter after injection to prevent tip adherence to the vessel wall, with the potential of losing hard-earned vascular access. With this system, access to the feeding artery can still be maintained, and a smaller microcatheter can conveniently be re-introduced into the target vessel without losing access and time should the embolisation be inadequate in the first attempt. Additionally, when withdrawing, the larger 2.7-Fr microcatheter can also serve another function of scraping off any adhered NBCA or Onyx casts on the smaller microcatheter tip, which can safely be flushed away to a safe site.

In a similar vein, the other benefit of the system is that in situations where the smaller microcatheter needs to be discarded after delivery of the payload, such as luminal blockage of the catheter due to the NBCA cast, or in the instance of TARE when more than one injection is required, to avoid contamination; a good practice would be to discard the microcatheter utilised for the delivery of the radionuclide due to residual activity (18), the vascular access can safely be maintained with the 2.7-Fr. intermediate microcatheter. This is coined the “pump-and-dump” technique by the authors.

All ten procedures using the triaxial system were performed within acceptable parameters in the current literature, especially from a radiation point of view. The means of fluoroscopy time and dose area product (DAP) of patients undergoing TACE in
the current literature ranges from 2.7–48.7 minutes and 20.46–615.74 Gy.cm\(^2\) respectively (19), for BAE ranges from 10.9–46.5 minutes and 72.20–314.53 Gy.cm\(^2\) (18), for embolisation of Type II endoleak ranges from 14.3–44.5 minutes and 109.72–302.54 Gy.cm\(^2\) (20) and for PAE ranged from 15.5–48.3 minutes and 248.3–791.73 Gy.cm\(^2\) (21).

Besides the cases mentioned above, the triaxial system can be utilised for embolisation of lower gastrointestinal bleeding (22) and re-embolisation for the recanalisation of pulmonary arteriovenous malformations (23).

Although the triaxial system shows superiority over the conventional coaxial system when using liquid embolic agents such as NBCA and Onyx, given the smaller inner diameter of the smaller microcatheter, there are limitations to the size of particulate embolic agents such as PVA particles, microspheres, beads, and coils that can be used. The system will accommodate only particles smaller than < 300µm, smaller gelatin sponge particles, and 0.014-inch microcoils. Larger particulate embolic agents may result in the occlusion of the microcatheter. Therefore, the recommended size of embolic agents must be available in the inventory before using the triaxial system.

Another drawback would be the higher cost due to an additional microcatheter's usage, adding approximately 200 USD more locally. Nevertheless, when faced with challenging vascular anatomy with an extended access route, the triaxial system could prove to be advantageous. We also believe the additional cost is justified, as it shortens the procedure time, which translates to lesser radiation exposure and possibly lower risk of more adverse events.

**Conclusion**

The triaxial system appears to be a valuable system that can be utilised for a myriad of conditions, mainly when complex embolisation procedures are performed. Nevertheless, additional studies with a larger cohort are required to further substantiate this technique's usefulness.

**Abbreviations**

- N-butyl cyanoacrylate (NBCA) glue
- Dimethyl-sulfoxide (DMSO)
- Hepatocellular carcinoma (HCC)
- Bronchial artery embolisation (BAE)
- Prostate artery embolization (PAE)
- Benign prostatic hyperplasia (BPH)
- Transarterial chemoembolisation (TACE)
- Transarterial radioembolisation (TARE)
- Barcelona Clinic Liver Cancer (BCLC)
- Yttrium-90 (Y-90)
- Polyvinyl alcohol (PVA)
- Endovascular Aneurysm Repair (EVAR)
- Inferior mesenteric artery (IMA)
Declarations

1. Ethics approval and consent to participate (Retrospective case series) – “For this type of study formal consent is not required.”
2. Consent for publication – All authors consent for the manuscript to be published at CVIR Endovascular.
3. Availability of data and materials – Data and material used in this manuscript can be made available on request.
4. Competing interests - “The authors declare that they have no conflict of interest.”
5. Funding – Article processing charges will be borne by Tokai Medical Products Inc, Kasugai, Japan.
6. Authors’ contribution – All authors were involved in drafting of manuscript and performing at least one of the cases shown in this series.
7. Acknowledgements – None

References


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**Figures**
Figure 1

Sketch showing the composition of a conventional coaxial system. It consists of a 0.014 to 0.018-inch microguidewire (small arrow), a microcatheter usually ranging from 2.0 to 2.9-Fr. (arrow head), inserted via the 4 or 5-Fr. catheter (large arrow).
Figure 2
Sketch showing the composition of a triple coaxial system. The triaxial system consists of a 0.014-inch microguidewire (small arrow head), 1.6-Fr. microcatheter (small arrow), a 2.7 to 2.9-Fr. intermediate microcatheter (large arrow head), a 4 to 5-Fr. catheter (large arrow).

Figure 3
(a) Digital subtraction angiography (DSA) performed via 2.7-Fr. high-flow microcatheter (arrow head) in a 78-year-old man showing multifocal HCC (arrows) in the right lobe of the liver. (b) Superselective TACE was performed for the tumor in segment 7 from a distal branch of a subsegmental artery using the triaxial system (small arrow - small 1.6-Fr. microcatheter; large arrow – 2.7-Fr. intermediate microcatheter). (c) Post-TACE spot radiograph obtained showing lipiodol staining of the tumour (arrow head) and adjacent portal veins in the embolised region.

Figure 4
(a) DSA of the right inferior phrenic artery (RIPA) arising from the left gastric artery in a 74-year-old woman with a large HCC in the right lobe of the liver. The patient is planned for radioembolisation with yttrium-90 (Y-90). The HCC is noted is be partly supplied by the posterior (inferior) branch of the RIPA (arrow), as noted from this angiogram. (b) Superselective catheterization of the posterior branch of the RIPA performed with a triaxial system (small arrowhead – 0.014-inch microguidewire; small arrow - small 1.6-Fr. microcatheter; large arrowhead - 2.7-Fr. intermediate microcatheter; large arrow – 4-
Fr. catheter). Coil embolisation of the anterior (superior) branch of the RIPA was performed followed by delivery of the Y-90 microspheres into the posterior branch (not shown).

Figure 5

(a) Angiogram of the right subclavian artery in a 72-year-old man presenting with massive haemoptysis due to prior pulmonary tuberculosis. Abnormal supply to the right upper lobe is noted from the lateral thoracic artery (arrow). Note the embolisation coils (arrowhead) deployed prior to this angiogram in the right intercostal bronchial trunk due to the presence of bronchial artery-pulmonary vein shunts. (b) Successful selective catheterisation of the offending branch was performed using a triaxial system (small arrow - small 1.6-Fr. microcatheter; large arrow - 2.7-Fr. intermediate microcatheter; arrowhead – 4-Fr. catheter), after multiple attempts to cannulate this branch with a conventional coaxial system failed.