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SHORT COMMUNICATION

Triaxial system in bronchial arterial embolization for haemoptysis using *N*-butyl-2-cyanoacrylate

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Objective: The application of bronchial artery embolization (BAE) using *N*-butyl-2-cyanoacrylate (NBCA) for haemoptysis was recently reported to be useful. A triple co-axial (triaxial) system consisting of a 4-Fr catheter, 2.7-Fr microcatheter and 1.9-Fr no-taper microcatheter has been developed. The aim of the present study was to evaluate the usefulness of the triaxial system in BAE using NBCA.

Methods: 12 patients with haemoptysis, 8 males and 4 females with a median age of 64 years (range, 49–88 years), underwent BAE between August 2012 and October 2014. Medical records and images were reviewed, and the technical success rate, clinical success rate, haemoptysis-free rate and complications were evaluated. Technical success was defined as the complete cessation of the target artery as confirmed by digital subtraction angiography,

whereas clinical success was defined as the cessation of haemoptysis within 24 h of BAE. Recurrent haemoptysis was defined as a total of >30 ml of bleeding per day.

Results: The target artery was embolized successfully in all patients, and the technical success rate was 100% (12/12). The cessation of haemoptysis was achieved in 11 out of 12 patients within 24 h, and thus, the clinical success rate was 92% (11/12). The 6-, 12- and 24-month haemoptysis-free rates were 89%, 89% and 76%, respectively. No patients exhibited any signs of complications such as spinal ischaemia.

Conclusion: BAE using the triaxial system and NBCA appears to be a useful and safe procedure for haemoptysis.

Advances in knowledge: The triaxial system contributes to safe and effective BAE using NBCA.

INTRODUCTION

Bronchial arterial embolization (BAE) is an established procedure for the management of haemoptysis. Recent studies^{1–4} suggested the application of *N*-butyl-2-cyanoacrylate (NBCA) as an embolic material in BAE for haemoptysis. However, superselective catheterization is important for avoiding spinal feeders and the reflux of embolic material into the aorta.¹ However, a new 1.9-Fr no-taper microcatheter has recently become available and can be inserted into a 2.7-Fr microcatheter. This new technique, the triple co-axial (triaxial) system, has been shown to contribute to superselective catheterization because the 1.9-Fr no-taper microcatheter can be inserted more distally with good support by the 2.7-Fr microcatheter.⁵ The aim of the present study was to evaluate the usefulness of the triaxial system using NBCA in BAE for haemoptysis.

METHODS AND MATERIALS

This retrospective study was approved by the Institutional Review Board, and written informed consent for the procedure

was obtained from each patient. 12 patients, 8 males and 4 females with a median age of 64 years (range, 49–88 years), underwent BAE for haemoptysis between August 2012 and October 2014. Amount of haemoptysis was defined as follows: massive, >240 ml day⁻¹; moderate, >100 ml day⁻¹; and small, ≤100 ml day⁻¹, as reported previously by Woo et al.¹ BAE was performed using the triaxial system with NBCA (by MS, TH, SA and TH). Medical records and images of the procedures were reviewed, and the technical success rate, clinical success rate and complications were evaluated (by MS, MN, YO, KS and YS).

Technical success was defined as the complete cessation of the target artery as confirmed by digital subtraction angiography (DSA). The DSA images were interpreted by two radiologists (MS and TH, both with 13 years' experience in diagnostic and interventional radiology). Any discrepancies were resolved by consensus. Clinical success was defined as the cessation of haemoptysis within 24 h of BAE, as reported previously by Woo et al.¹ Close observation for

Table 1. Details of bronchial artery embolization and outcome

Case Number	Aetiology	Degree of haemoptysis	Extravasation	Approach	Embolized artery	Embolic agent	Technical success	Clinical success	Complication	Follow-up period (months)	Recurrent haemoptysis
1	Aspergilloma	Massive	No	Lt Bra A	Rt BA, Rt 5th ICA	NBCA and GS	Yes	Yes	No	0.5	Yes
2	Bronchiectasis	Moderate	No	Rt FA	Rt 5th ICA, Rt IMA	NBCA and GS	Yes	Yes	No	3	No
3	Obsolete tuberculosis	Moderate	No	Rt FA	Lt IPA, Lt LTA	NBCA	Yes	Yes	No	9	Yes
4	Bronchiectasis	Moderate	No	Rt FA	Rt BA	NBCA	Yes	Yes	No	13	No
5	Bronchiectasis	Moderate	No	Rt FA	Rt BA	NBCA and coils	Yes	Yes	No	13	No
6	Bronchiectasis	Moderate	No	Rt FA	Lt BA, Lt IPA	NBCA and GS	Yes	Yes	No	18	No
7	Bronchiectasis	Moderate	No	Rt FA	Lt BA, Lt IPA	NBCA and GS	Yes	Yes	No	23	No
8	Obsolete tuberculosis	Moderate	No	Rt FA	Lt BA, Lt 9th ICA	NBCA	Yes	Yes	No	23	No
9	Bronchiectasis	Small	No	Rt FA	Rt 5th, 6th, 7th, 8th ICA, Rt IPA	NBCA	Yes	Yes	No	31	No
10	Aspergilloma	Moderate	No	Rt FA	Lt BA, Lt 5th, 6th ICA	NBCA and GS	Yes	No	No	Lobectomy	No
11	Aspergilloma	Massive	No	Rt FA	Lt BA, Lt LTA	NBCA and GS	Yes	Yes	No	Not followed	
12	Obsolete tuberculosis	Massive	No	Rt FA	Lt BA	NBCA	Yes	Yes	No	Not followed	

BA, bronchial artery; Bra A, brachial artery; FA, femoral artery; GS, gelatin sponge; ICA, intercostal artery; IMA, internal mammary artery; IPA, inferior phrenic artery; Lt, left; LTA, lateral thoracic artery; NBCA, *N*-butyl-2-cyanoacrylate; Rt, right.

Figure 1. An 88-year-old male presented with haemoptysis from obsolete tuberculosis. (a) Angiography of the bronchial artery shows hypervascular inflammatory parenchymal lesions at distal sites (arrows). (b) Using the triaxial system (2.7-Fr microcatheter, Sniper 2 high-flow; Terumo Clinical Supply Co., Ltd, Gifu, Japan: large arrow, 1.9-Fr no-taper microcatheter, MARVEL, Tokai Medical, Kasugai, Japan: small arrow), the tip of the 1.9-Fr no-taper microcatheter was advanced to the distal site of the branch of the bronchial artery. Embolization with *N*-butyl-2-cyanoacrylate (NBCA) and iodized oil mixture (ratio, 1:4) was then achieved, and the 1.9-Fr no-taper microcatheter was removed immediately. (c) After embolization, angiography showed complete occlusion of this branch without occlusion of the proximal site of the bronchial artery because the 2.7-Fr microcatheter may scrape the cast off the 1.9-Fr no-taper microcatheter in the bronchial artery. (d) Another branch was selected with the 1.9-Fr no-taper microcatheter (small arrow), and this selective catheterization was easy to perform because the 2.7-Fr microcatheter (large arrow) may be left in the bronchial artery. Embolization was again performed with NBCA. (e) Angiography shows the complete occlusion of this branch, and the recurrence of haemoptysis or complications were not detected in this patient during a follow-up of 23 months.

early complications of BAE was conducted during the procedure and post-procedural admission. Delayed complications were assessed at the follow-up during outpatient or emergency department visits. Complications associated with the procedure were evaluated by physical examinations and blood tests to check chest pain, recurrent haemoptysis and neurological symptoms.

Recurrent haemoptysis was defined as a single or multiple episodes of haemoptysis causing a total of >30 ml of bleeding per day, as reported previously by Anuradha et al.⁶ Haemoptysis-free rates were estimated

using the Kaplan–Meier method. The follow-up period was defined as the duration until the last hospital visit or date of death.

Technique of BAE using the triaxial system for haemoptysis

11 out of 12 procedures were approached *via* the right femoral artery with a 4-Fr sheath. The remaining procedure was approached *via* the left brachial artery with a 6-Fr guiding sheath because the aorta of this patient was markedly bent owing to a severe stoop and appeared to be difficult to approach from the femoral artery. Angiography of the bronchial and non-bronchial

Figure 2. Kaplan-Meier estimated curves of haemoptysis-free survival of the nine patients who were successfully followed-up. The 6-, 12- and 24-month haemoptysis-free rates were 89%, 89% and 76%, respectively.

systemic collateral arteries was obtained with a 4-Fr catheter, and the triaxial system, consisting of a 2.7-Fr microcatheter (Sniper 2 high-flow; Terumo Clinical Supply Co., Ltd, Gifu, Japan) and 1.9-Fr no-taper microcatheter (MARVEL; Tokai Medical, Kasugai, Japan), was then introduced. A 0.014-inch microguidewire (BEGIN; ASAHI INTECC, Nagoya, Japan) was used in all cases. The tip of the 1.9-Fr no-taper microcatheter was advanced co-axially as close to the bleeding portion as possible, and the target artery was then embolized with NBCA. NBCA was mixed with iodized oil at a ratio of 1:2 to 1:4. After the microcatheter was flushed with 5% dextrose solution to avoid gluing and occlusion of the lumen during the injection of NBCA, 0.5–2 ml of the mixture was carefully injected under fluoroscopic monitoring. The ratio, volume and injection rate of the mixture were based on the size and flow of the embolization vessels. The 1.9-Fr no-taper microcatheter was quickly removed after the injection in order to avoid adhesion of the catheter tip to the vessel wall. Angiography was subsequently performed from the 2.7-Fr microcatheter to confirm complete cessation of the target artery.

RESULTS

The aetiology of haemoptysis was bronchiectasis in six patients, obsolete tuberculosis in three patients and aspergilloma in three patients. Contrast-enhanced CT was performed in all patients, and the bleeding site and feeding artery were confirmed before BAE. Details of BAE and patient outcomes are summarized in

Table 1. There was no extravasation in all cases. The amount of haemoptysis was massive in three patients, moderate in eight patients and small in one patient. Only the bronchial artery was embolized in three patients, only the non-bronchial systemic artery was embolized in three patients and both were embolized in six patients. The median number of embolized arteries was two (range, one–five). NBCA only was used in five patients, NBCA and a gelatin sponge were used in six patients and NBCA and coils were used in one patient. In all cases, NBCA was basically used for the artery, which appeared to be the major vessel of haemoptysis. Only the gelatin sponge was used for an artery that appeared to be a minor vessel in order to economize the number of the microcatheters because the inside of the microcatheter was occluded after using NBCA and, thus, was difficult to use again. Since an aneurysm was detected in the bronchial artery of one case, the distal site of the bronchial artery was embolized with NBCA, and the aneurysm was embolized with coils.

Embolization of the target artery was performed successfully in all 12 cases. The 1.9-Fr no-taper microcatheter was inserted into the bleeding portion and embolization was successfully performed. Complete cessation was confirmed by DSA at the end of all procedures. Therefore, the technical success rate was 100% (12/12) (Figure 1). The cessation of haemoptysis was obtained in 11 out of 12 cases within 24 h; however, haemoptysis recurred within 24 h in the remaining case. Therefore, the clinical success rate was 92% (11/12). Although re-BAE was performed twice in this failure case because of a supply from the collateral branch of the subclavian artery, resulting in the cessation of haemoptysis, this patient underwent lobectomy to achieve a complete treatment.

2 out of 12 patients moved to another hospital and could not be followed-up, whereas 1 patient underwent lobectomy. The remaining nine patients were followed-up, with a median follow-up period of 15.5 months (range, 0.5–31 months). Haemoptysis recurred in two out of these nine patients, who died 15 days and 9 months after BAE, respectively. No recurrence was observed in the seven other patients. The 6-, 12- and 24-month haemoptysis-free rates were 89%, 89% and 76%, respectively (Figure 2). No complications such as spinal ischaemia were observed following BAE in any case.

Figure 3. Diagram showing the advantage of the triaxial system in removing the microcatheter. When removing the microcatheter in the conventional system, a cast of *N*-butyl-2-cyanoacrylate (NBCA) may adhere to the tip of the microcatheter, resulting in the risk of migration of the cast to the aorta or spinal branch. Even when a cast of NBCA adheres to the tip of the 1.9-Fr no-taper microcatheter in the triaxial system, the 2.7-Fr microcatheter can scrape the cast off to the distal site.

DISCUSSION

Many embolic agents including a gelatin sponge, polyvinyl alcohol (PVA) particles and NBCA are used in BAE to treat haemoptysis. Each material has its own advantages and disadvantages. A gelatin sponge is cost-effective and its size can be controlled. However, recanalization may occur faster than with PVA because the gelatin sponge is absorbed spontaneously. Hahn et al⁷ reported that PVA was superior to a gelatin sponge for long-term outcomes in BAE. On the other hand, NBCA has attracted interest for the control of bleeding from various organs because of its advantages as an embolic agent. The rapid and complete occlusion of target vessels results in more reliable embolization and reductions in fluoroscopic and procedural times, and the adjustable ratio of NBCA to iodized oil allows the polymerization time and level of embolization to be controlled within target vessels.^{2,3} Despite these advantages, NBCA has been avoided in BAE because of the high risk of severe complications, such as tissue necrosis and non-target embolization from uncontrolled reflux.^{4,8}

Woo et al¹ recently reported that NBCA was superior to PVA for the prevention of recurrent haemoptysis without increasing complication rates. Haemoptysis-free rates were significantly higher in patients who underwent BAE with NBCA than in those who underwent BAE with PVA. This enhanced effectiveness was, at least partly, attributed to NBCA being a more durable embolic material than PVA. Furthermore, differences in the level of embolization may explain why BAE with NBCA resulted in lower recanalization rates. NBCA, which is a semi-fluid, exits the microcatheter tip as 1- to 2-mm droplets, which renders it possible to reach and occlude the distal vascular beds. One concern regarding liquid embolic agents, including NBCA, is the possibility of tissue necrosis, including the aorta or bronchi.^{3,8,9} However, recent studies²⁻⁴ successfully performed BAE with NBCA without such complications. Ikoma et al¹⁰ performed a pathological evaluation of a resected lung from a patient who underwent BAE with NBCA and demonstrated that although NBCA was observed in bronchial arteries that were ≤ 300 μ m in diameter, it caused no ischaemic damage to the bronchial artery or pulmonary parenchyma.

The most severe complication is the inadvertent embolization of a spinal artery leading to ischaemia and paralysis. The incidence of spinal artery ischaemia from bronchial artery embolization was previously reported to be between 1.4% and 6.5%.⁸ Even though radicular arteries exist at every level to supply the dorsal and ventral roots, only a few medullary arteries supply the anterior spinal artery. The embryological regression of blood supply to the anterior spinal cord and relatively large area supplied by each anterior spinal artery makes it very susceptible to ischaemia during interventions.¹¹ Thus, superselective catheterization distal to the spinal artery feeder is very important in BAE in order to minimize spinal ischaemia.⁶ The triaxial system was recently shown to be

a good method for superselective catheterization and has been applied under various conditions.^{5,12,13} It was easier to advance the 1.9-Fr no-taper microcatheter into the target vessel using the triaxial system because the 2.7-Fr microcatheter stabilized the position and prevented sagging or jumping. Furthermore, by inserting the 1.9-Fr no-taper microcatheter, the gap between the 2.7-Fr microcatheter and microguidewire became smaller. Therefore, the 2.7-Fr microcatheter was inserted more distally along the 1.9-Fr no-taper microcatheter and microguidewire, and as a result, the 1.9-Fr no-taper microcatheter was also inserted more distally with good back up from the 2.7-Fr microcatheter. Woo et al¹ also reported technical failures in 17 out of 293 cases (5.8%) due to the following difficulties 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. The triaxial system may be applied to overcome these issues.

Another two advantages of the triaxial system with NBCA are as follows. Difficulties have been reported with the handling of NBCA, and the catheter tip may adhere to the vessel wall because of its rapid polymerization.¹⁴ Thus, the microcatheter needs to be removed immediately after embolization in order to prevent adherence of the catheter tip to the vessel wall. Even if the first attempt using the triaxial system is insufficient and the 1.9-Fr no-taper microcatheter must be removed, the 2.7-Fr microcatheter can be left at the feeding artery. Therefore, selective catheterization does not need to be repeated, and another 1.9-Fr no-taper microcatheter can be easily inserted into the target portion.¹⁵ Furthermore, the cast of NBCA sometimes adheres to the tip of the microcatheter when removing the microcatheter. In the conventional system consisting of a 4 or 5-Fr catheter and microcatheter, this situation may result in migration of the cast to the aorta or the spinal branch because only the tip of the 4 or 5-Fr catheter is typically placed into the orifice of the bronchial artery. However, in the triaxial system, the 2.7-Fr microcatheter can scrape the cast off the 1.9-Fr no-taper microcatheter in the bronchial artery, and the cast can then be carried away to the distal site (Figure 3).

In the present study, superselective catheterization of the target artery was achieved in all cases (technical success rate: 100%) using the triaxial system, and haemoptysis was mostly controlled with NBCA embolization (clinical success rate: 92%) without any complications. In one case, re-BAE and lobectomy were required because of a supply from the collateral branch of the subclavian artery. Thus, it is important to embolize all branches that may act as a collateral supply, especially in branches of the subclavian artery. Furthermore, although such branches may be small and tortuous, the triaxial system may contribute to superselective catheterization even in such difficult branches.

In conclusion, the triaxial system using NBCA appeared to be useful in BAE for haemoptysis.

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