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Research Article

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Is Cone-Beam Computed Tomography Feasible in Detecting Spinal Artery Branches and Esophageal Wall Enhancement During Transarterial Embolization or Infusion for Thoracic Diseases?

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Abstract

Transarterial embolization and transarterial infusion is well-accepted and widely used nowadays. However, bronchial arterial anatomy is highly variable and commonly associated with arterial supplies to other structures including spinal, esophagus and pericardium. Then severe complications, such as spinal cord injury, esophageal ulceration and bronchoesophageal fistula may happen because of inadvertent embolization of the esophageal and spinal vessels. This study aims to evaluate the role of cone-beam computed tomography (CT) in detecting spinal artery branches and esophageal wall enhancement to reduce severe complications, such as spinal cord injury and bronchoesophageal fistula, during transarterial therapy for thoracic diseases. In the present study, data from 68 patients with thoracic diseases were collected via plain digital subtraction angiography (DSA) and cone-beam CT before transcatheter arterial embolization or infusion, including 67 bronchial/ intercostal-bronchial trunk (ICBT) arteriograms and 18 intercostal arteriograms, and the cone-beam CT was reconstructed from the volume dataset. Two radiologists respectively evaluated whether there were spinal artery branches or esophageal wall enhancement from the bronchial/ICBT artery and the intercostal artery via plain DSA or cone-beam CT. The detection rates of cone-beam CT and plain DSA were compared using McNemar's test. The results showed that spinal artery branches were detected in 12 patients in cone-beam CT, while only 4 patients were detected in plain DSA. There was significant difference of detection rate in spinal artery branches between cone-beam CT and plain DSA (P=0.008). There were 18 patients of esophageal wall enhancement detected in cone-beam CT, while only 1 patient was detected in plain DSA. The detection rate of esophageal wall enhancement was significantly higher in cone-beam CT than those of plain DSA (P<0.01). There was no severe complication occurred after the procedure. In conclusion, cone-beam CT can detect the spinal artery branches and esophageal wall enhancement better than plain DSA.

Keywords: Cone-beam computed tomography; Digital subtraction angiography; spinal artery; Esophagus; Injury

Introduction

Transarterial Embolization (TAE) and Transarterial Infusion (TAI) have become well-accepted and widely used procedures for patients with life-threatening hemoptysis or lung cancer who are unsuitable for surgical resection, since the first report on 1964 [1]. The efficacy, safety and utility of these techniques have been well documented in many subsequent reports, especially with the development of microcatheter system, which has the advantage of precise placement and stability through super-selective bronchial or intercostal arterial catheterization [2,3]. Bronchial arterial anatomy is highly variable and commonly associated with arterial supplies to other structures including spinal, esophagus and pericardium. Then severe complications, such as spinal cord injury, esophageal ulceration and bronchoesophageal fistula may happen because of inadvertent embolization of the esophageal and spinal vessels [4-7]. Additionally, several studies found that most of the small branches that supply blood to the spinal cord or esophagus may be invisible on plain Digital Subtraction Angiography (DSA), while these small branches may be defined with Computed Tomography (CT) angiography before procedure [8]. However, the radiation dosage and the effects of contrast agents of CT angiography on patients should be considered. Cone-beam CT is an advanced imaging technology in the interventional radiology suite, which can provide multiplanar cross sectional and Three-Dimensional (3D) images like CT angiography during the procedure [9]. To date, there have been no reports illustrating whether cone-beam CT can detect spinal artery branches or esophageal wall enhancement more effectively than plain DSA.

Materials and Methods

Patients' characteristics

This retrospective study was approved by the institutional review board in accordance with approved guidelines of our hospital and was compliant with HIPAA. Written informed consent was waived due to the retrospective nature of the study. Between September 2015 and December 2017, 68 consecutive patients with thoracic diseases were admitted to our hospital. Fifty-two men and sixteen women who underwent both cone-beam CT and plain DSA were included. The mean age of the patient was 61.1±11.1 years (range from 27 to 77 years). The clinical records were reviewed, and the following data and images were collected for analysis: age, gender, clinical features, all available arteriograms, chest cone-beam CT scans, the results or complications related to the procedure. The clinical data of all patients were summarized in Table 1.

Table1: Clinical characteristics of 68 patients in the present study.

Parameters	Total (n=68)
Age distribution mean +SD, (yrs)	61.1±11.1

Gender	
Male: Female	52:16:00
Etiology	
Hemoptysis: Lung cancer	09:59
BA/ICBT: ICA	67:18:00

Note: BA: Bronchial Artery; ICBT: Intercostal-Bronchial Trunk; ICA: Intercostal Artery

Interventions

All patients had normal renal functions and coagulation profiles at the time of the procedure. Catheterization of the Bronchial/Intercostal-Bronchial Trunk (ICBT) artery and intercostal artery was performed by the standard Seldinger technique under local anesthesia using a 5.0-French catheter. After catheterization, the cone-beam CT angiography was performed. Then, a coaxial microcatheter was inserted, and selective angiography was performed. The cone-beam CT protocols for thoracic arterial interventions were summarized in **Table 2**. All data from angiographic examinations was transferred to the backend computer systems of the cone-beam CT, and then the images were visualized in multiplanar reconstruction formats on the workstation. The material used in most patients was cisplatin (50 mg) for TAI and a combination of Polyvinyl Alcohol (PVA) particles and stripped Gelatin Sponge (GS) for TAE.

Table 2: Cone-beam computed tomography protocols for thoracic arterial interventions.

Parameters	
Target artery	BA/ICBT/ ICA
Rate of injection (mL/sec)	0.5-1
Delay exposure time (sec)	5s
Total volume contrast agent (mL)	5-10mL
Contrast agent dilution	1:4 (contrast: normal saline)
Breath holding	Yes
Rotation time (degree/sec)	40
Rotation degree	200

Note: BA: Bronchial Artery; ICBT: Intercostal-Bronchial Trunk; ICA: Intercostal Artery

Imaging analysis

Two radiologists with either 10 years or 12 years of chest imaging experiences reviewed the imaging, respectively. They were all blinded to the clinical data. Spinal artery branches or esophageal wall enhancement from the bronchial/ICBT artery or the intercostal artery via cone-beam CT as well as plain DSA were recorded.

Statistical analysis

The detection rates of spinal artery branches or esophageal wall enhancement between cone-beam CT and plain DSA were compared using McNemar's test. The inter-rater agreement between two radiologists were calculated using Kappa test. Consistency was classified as poor (K, 0-0.40), fair to good (K, 0.40-0.75), or excellent (K, >0.75).

Results

The plain DSA and cone-beam CT were successfully performed in all 68 of the patients, with 67 bronchial/ICBT arteriograms and 18 intercostal arteriograms. There were 12 patients detected spinal artery branches in cone-beam CT, while only 4 patients detected spinal artery branches in plain DSA **(Figure 1 and 2)**. The detection rate of spinal artery branches from the bronchial/ICBT artery was 11.9% (8/67) and that from the intercostal artery was 22.2% (4/18). There was significant difference of detection rate in spinal artery branches between cone-beam CT and plain DSA (P=0.008). For the detection of esophageal wall enhancement, 18 patients were detected in cone-beam CT, while only 1 patient detected in plain DSA **(Figure 3)**. All the 18 patients of esophageal wall enhancement were from the bronchial/ICBT artery, and the rate was 26.9% (18/67). The detection rate of esophageal wall enhancement was significantly higher in cone-beam CT than those of plain DSA (P<0.01). There were no severe complications such as esophageal ulceration, bronchoesophageal fistula and spinal cord injury occurred after the procedure.

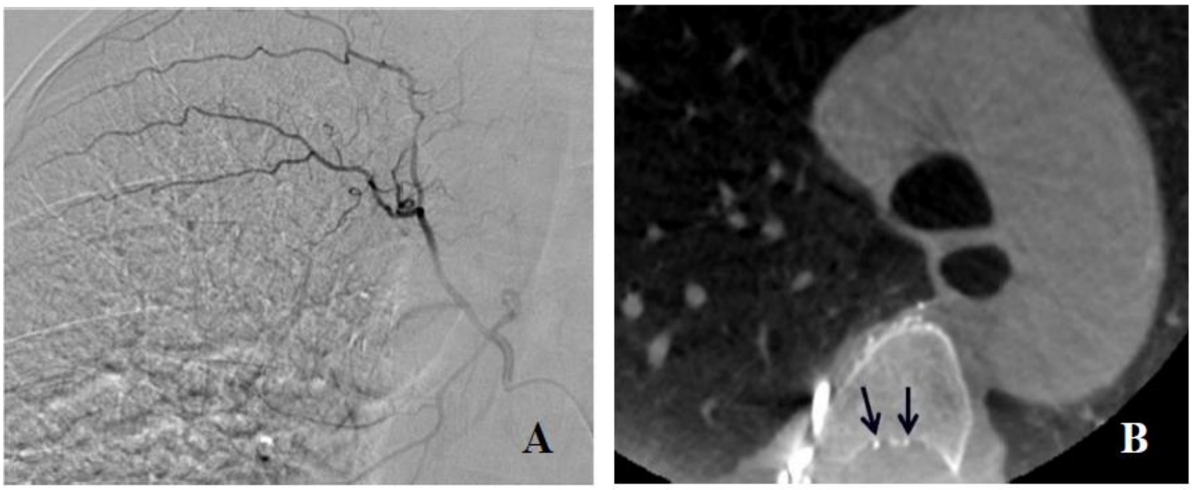

Figure 1: A 57 years old male with lung cancer underwent transarterial infusion. The right ICBT arteriogram shows no spinal artery branch (A). Cone-beam CT confirms the spinal artery branches clearly (black arrow) (B).

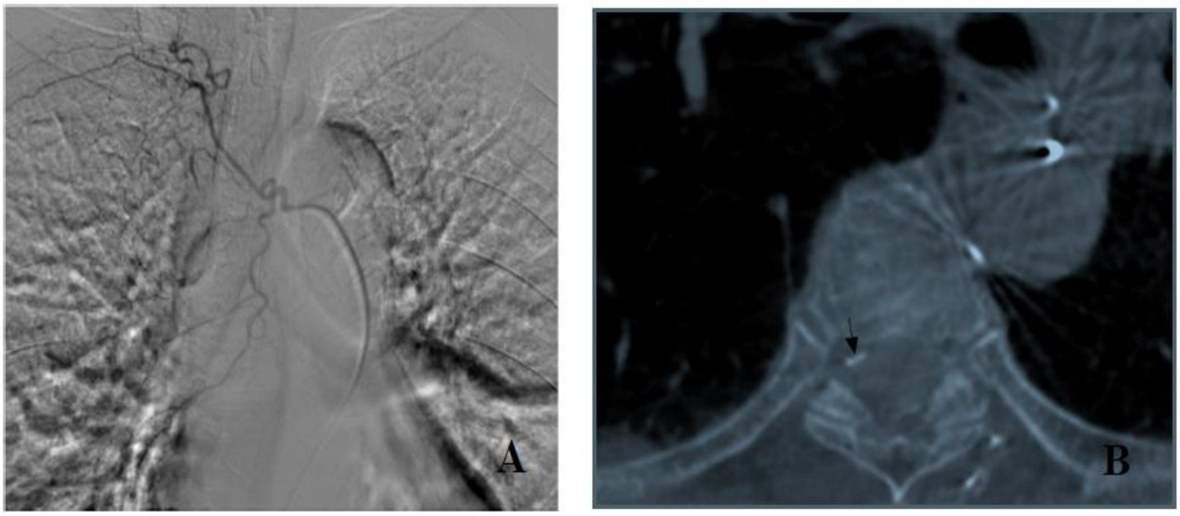

Figure 2: A 73 years old female with lung cancer underwent transarterial infusion. Plain DSA via right ICBT artery shows no spinal artery branch (A). Cone-beam CT confirms the spinal artery branches clearly (black arrow) (B).

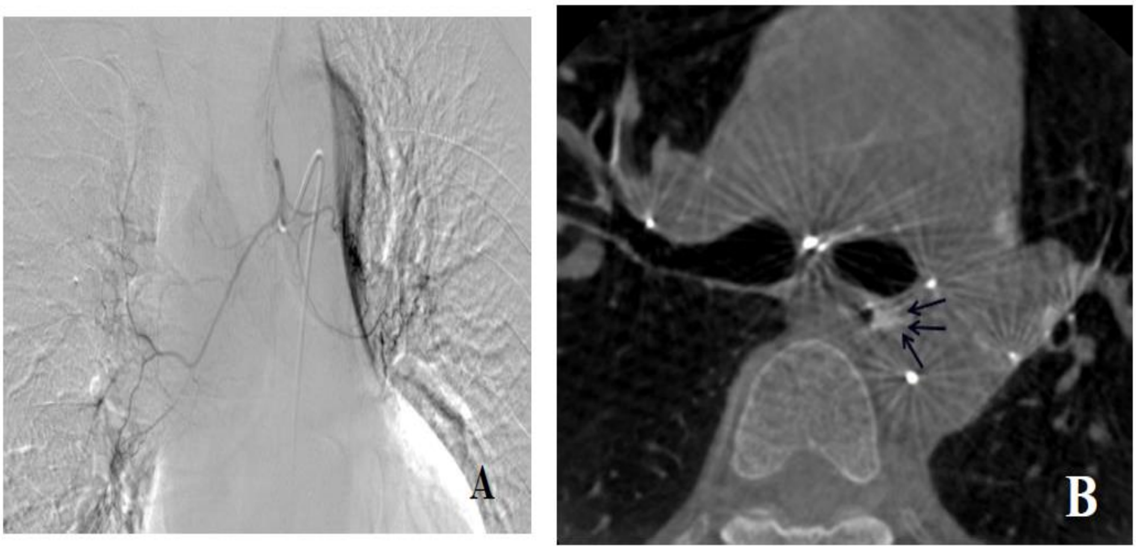

Figure 3: A 42 years old male with hemoptysis underwent transarterial embolization. Angiogram via the origin of the bronchial artery. Neither spinal nor esophageal branches can be found on plain DSA (A). Esophageal wall enhancement (black arrow) via the left bronchial artery is seen on Cone-beam CT (B).

The inter-rater agreement of the detection of spinal artery branches or esophageal wall enhancement between two radiologists was excellent (Kappa=0.914 or 0.814, respectively).

Discussion

TAE and TAI are established techniques in the management of patients with life-threatening hemoptysis and inoperable thoracic tumors. However, several complications of TAE and TAI have been reported in the literature. The most severe complications, such as esophageal ulceration, bronchoesophageal fistula and spinal cord injury appeared after transcatheter arterial therapy, because spinal and esophageal branches not being visualized on DSA images. For this reason, the anti-cancer drug or embolic material infused via the bronchial or intercostal artery was distributed into the esophageal or spinal vessels. The incidence of spinal cord ischemia from bronchial artery embolization is reported to be between 1.4% and 6.5% [10]. Esophageal ulceration or bronchoesophageal fistula occurred in 1.1% of cases during TAI [11]. Recently, the claim that the visualization of spinal or esophageal artery branches is a contraindication to embolization has been allayed by the microcatheter systems that allow catheter placement distal to the spinal or esophageal artery feeder. However, some case has demonstrated that the possibility of ectopic embolization causing severe complications may not be eliminated despite all typical precautions [12]. And if it happens, the consequences would be disastrous. Hence, avoiding the delivery of drugs and embolic material into nontarget organ arteries and the visualization of the spinal or esophageal branches is important to prevent such complications. Nevertheless, the existence of extremely small anastomoses between the bronchial arteries and the spinal or esophageal branches may not be detectable by plain DSA alone. Some studies have demonstrated the role of CT angiography prior to transarterial therapy for thoracic diseases for the prevention of severe complications. Osamu Tanaka et al. [13] performed selective CT angiography using a coaxial microcatheter for 28 patients before TAE and TAI chemotherapy. Their results showed that the spinal artery branches were observed in 2 (7.1%) patients and enhancement of the esophageal wall in 1 (3.6%) patient. When performing CT angiography, more procedure time, more contrast load and more radiation exposure are needed, thus, CT angiography may not be the most suitable modality for this evaluation. In the present study, esophageal wall enhancement was observed in 18 patients (26.9%), and spinal artery branches were found in 12 patients (17.6%) via cone-beam CT. The detection rate of the esophageal wall enhancement was lower than those of previous study (26.9% vs. 48.7%) [14] probably because of the low-contrast tissue resolution of cone-beam CT compared to CT angiography and the scan require a long breath holding time during the examination, which may cause motion artifacts. And the rate of spinal artery branches supplied from the bronchial artery was 11.9% (8/67) and that from the intercostal artery was 22.2% (4/18), which was greater in the present study than those of previous studies (11.9% vs. 5% and 22.2% vs. 15%, respectively) [14]. These results suggested that the potential use of cone-beam CT can detect spinal artery branches more effectively because of the high-contrast tissue resolution with multiple viewing planes compared to plain DSA alone. So, it may help avoiding severe complications during transarterial therapy for thoracic diseases. There are some limitations in the present study. Firstly, like all retrospective studies, the comparison of cone-beam CT and plain DSA may be subject to selection bias. Secondly, the sample size of the present study is too small. A prospective study with a relatively large sample size should be conducted in the future.

In conclusion, this study demonstrates that cone-beam CT is better in detecting spinal artery branches and esophageal wall enhancement than plain DSA during TAE or TAI for thoracic diseases, and cone-beam CT may provide potential utility of reducing the incidence of severe complications.

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