CT Angiography Evaluation of Endoleak after Thoracic Endovascular Aortic Repair in Thoracic Aortic Aneurysm

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Objective: *Analyze the incidence and findings of endoleak after thoracic endovascular aortic repair by using CT angiography.*
Material and method: *Between August 2006 and December 2008, 68 patients diagnosed with thoracic aortic aneurysm underwent thoracic endovascular aortic repair and were included in the present study. The patients were 47 men and 21 women, with a mean age of 69 $\pm$ 9.4 years old. Thoraco-abdominal CT angiographic images (64-slice MDCT) after operation of 68 patients were retrospectively reviewed to evaluate incidence of endoleak and classify findings of endoleak.*
Results: *Endoleaks were detected in 26 patients (38.2%). There were type I endoleaks in three cases (11.5%), type II endoleaks in 22 cases (84.6%), and type III endoleaks in one case (3.9%). Type II endoleaks were detected as peritubular collection, mostly located at periphery of the aneurysm. Eleven cases (50%) of type II endoleaks were supplied by left subclavian artery. Twenty patients who had completed 1, 3, and 6 months follow-up CT angiography were selected for further evaluation of changing in size of aneurysm. The measurement of the thoracic aneurysm showed no decreasing of the maximum length of diameter and volume of the aneurysmal sac in endoleak group.*
Conclusion: *Follow-up CT angiography is useful for detection and characterization of endoleak after endovascular aortic repair of thoracic aneurysm. Most of type II endoleaks show peritubular (collection) shape and locate at the periphery. Patients with endoleak after thoracic endovascular aortic repair tend to continue to have sac expansion.*

Keywords: *CT angiography, Endovascular aortic repair, Aortic aneurysm, Multidetector row CT*

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After successful percutaneous transfemoral approach of stent graft placement for abdominal aortic aneurysm treatment or endovascular aortic repair (EVAR) was introduced by Parodi et al in 1991[1], this technique was widely used as an alternative to open surgical repair due to being less invasive and reduced operative risks and post operative complications. This endovascular technique was also applied to treat thoracic aortic aneurysm. The first case of thoracic endovascular aortic repair (TEVAR) was reported by Dake et al in 1994[2].

Currently, TEVAR has become an alternative method to treat thoracic aortic aneurysm. After endovascular stent graft placement, the excluded lumen is depressurized and most aneurysms subsequently shrink[3]. The persistence of blood flow within the excluded aneurysmal sac is so called endoleak that is one of a major complication after TEVAR. Follow-up imaging is needed to detect the endoleak. Contrast-enhanced CT angiography is a widely accepted imaging modality for use in follow-up of TEVAR[4].

The purpose of the present study was to evaluate the incidence, type, shape, and location of endoleak after TEVAR. According to the unique characteristic of type II endoleak which is different in both its mechanism and clinical presentation, type II endoleak is caused by non-endograft-related retrograde flow from a patent arterial collateral branch to perfuse the aortic lesion[5]. The enhancement in aneurysmal

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sac is not only the important features of the endoleak but also changing in size of aneurysmal sac. Tiny leakage of contrast to the aneurysmal sac may be difficult to visualize on CT angiographic image, thus progressive decreased in size of an aneurysmal sac is also an important sign of success of the treatment. The volumetric measurement of aneurysm required additional software and time-consuming process. The maximum diameter of aneurysm is easily measured on the routine practice. For this reason, the present study is also evaluated for correlation in size of aneurysmal sac between aortic diameter and volume measurement techniques.

Material and Method

Patients

The present study was approved by institutional review board for the retrospective review of CT scan in patients who underwent TEVAR. Between August 2006 and December 2008, 68 patients who had endovascular repair for treated thoracic aortic aneurysm were included in the present study. Of these 68 patients, only 20 patients had complete follow-up images until 6 months after stent graft implantation. These procedures were performed with the commercially available, Communaute Europeenne (CE)-approved devices: Valiant (Medtronic/AVE), TAG (W.L. Gore & Associates), and Zenith TX2 (Cook). Of these 68 patients, the study contained 47 men and 21 women, aged 46-94 years with a mean age of 69 ± 9.4 years.

CT acquisition

Before and after aneurysm repair, imaging by thoracic CT angiography was performed with 64-slice multidetector CT scanner, LightSpeed VCT (General Electric Medical System, Milwaukee, WI) or Somatom Definition (Siemens medical Solution, Erlangen, Germany). The CT protocol consisted of un-enhanced and arterial phase contrast-enhanced scans. No oral contrast agent was administrated. The CT acquisition was performed with the following parameter: pitch 1-1.5, 120 kV, 250-300 mAs, 1.25 mm collimation for LightSpeed VCT, and 1.5 mm collimation for Somatom Definition. On contrast-enhanced scan, 75-100 ml of nonionic contrast material (370 mgI/ml iopromide, Bayer Schering Pharma AG, Berlin, Germany) was administrated into an antecubital vein with a power injector at a rate of 4 ml/s. The CT acquisition was started at peak contrast arriving at ascending aorta using bolus-tracking technique.

Data analysis

All CT scan images were retrospectively reviewed to evaluate incidence of endoleak and classified for type, shape, and location of endoleak in consensus by two experienced cardiovascular radiologists using picture archiving and communication system (PACS). Axial, sagittal, coronal, volume-rendered (VR) images and maximum intensity projection (MIP) were used for imaging evaluation.

The types of endoleak were classified according to the Society for Vascular Surgery and the American Association for Vascular Surgery[6]. Type I was indicative of a persistent perigraft channel of blood flow caused by inadequate or ineffective seal at either the proximal or distal graft ends or attachment zones. Type II was attributed to retrograde blood flow from peripheral vessels. An endoleak caused by fabric tears or disruption, component disconnection, or graft disintegration was classified as a type III endoleak. Flow from porous fabric was classified with type IV endoleak. If an endoleak was visualized on imaging studies but the precise source cannot be determined, the endoleak was categorized as an endoleak of undefined origin.

Location of the aortic aneurysm was classified by anatomical location as ascending aorta (from aortic root to the origin of right brachiocephalic artery), proximal aortic arch (aorta at origin of brachiocephalic trunk), mid aortic arch (just distal to left common carotid artery), proximal descending thoracic aorta (2 cm distal to left subclavian artery), mid and distal descending thoracic aorta. Location of stent graft landing zone was defined according to the classification proposed by Criado et al[7], which were ascending aorta, zone 0 (if the stent cover brachiocephalic trunk), zone 1 (if the stent cover left common carotid artery), zone 2 (if the stent cover left subclavian artery), zone 3 (if the stent was distal to left subclavian artery), and zone 4 (if the stent was placing in descending thoracic aorta).

The shape and location of endoleak were recorded and classified according to findings proposed by Chernyak et al[8]. The shape of endoleak was classified as tubular (when its shape appeared as channel-like) or non-tubular. The location of the endoleak was categorized as central, peripheral, or combined, depending on the position of its components relative to the endovascular stent graft and the aortic wall. Central location was defined if the endoleak located abutting or conforming to the graft or seen within the aneurysm sac at distance from the wall whereas location of endoleak, which adjacent to wall without gap or with a gap less than 2 mm, was defined to peripheral location. For feeding vessel, the authors searched for small aortic branch directly contiguous to the aneurysmal sac.

After aneurysm repair, only 20 patients had complete follow-up CTA images performing at 1, 3, and 6 months after operation. For these 20 patients, endoleak was not found in 13 patients, whereas seven patients had type II endoleaks. Additional evaluation for diameter and volume of the aneurysms on the follow-up images was obtained by using available commercial software (Vitrea 2, Vital Images, Plymouth, MN). The maximum diameter of aneurysm was automatic measurement by tracking the central line of aortic lumen. Volumetric measurement was also performed with semiautomatic segmentation and divided into two drawing techniques depending on the aneurysm morphology. If the aneurysm appeared as fusiform shape, the aorta including within the stent graft was involved in the region of interest. For saccular shape, the region of interest was drawn from neck to the entire aneurysm, which was outside the stent graft.

Statistical analysis

Statistical analysis was computed with Statistical Package for the Social Sciences (SPSS), release version 13.0 for Windows. Categorical variables were evaluated by frequencies and percentage. The diameter and volume of aneurysm were calculated in Mean $\pm$ SD and tested for normal distribution by the Kolmogorov-Smirnov test and compared between two groups with unpaired Student t-test for normally distributed values. Otherwise, the Mann-Whitney U test was used. In case of dichotomous variables, such as stent graft landing zone and location of aneurysm, group differences were examined by Fisher Exact tests. The differences were considered significant if the two-tailed p-value was < 0.05. The linear relationship between diameter and volumetric measurement of aortic aneurysm was calculated by Pearson's correlation coefficient and values from -1.0 to 1.0 where -1.0 was a perfect negative correlation, 0.0 was no correlation and 1.0 was a perfect positive correlation. Values of less than 0.5 were indicative of poor correlation, values of 0.51 to 0.79 were indicative of moderate correlation, and values of more than 0.9 were indicative of good correlation.

Results

Between August 2006 and December 2008, 68 patients had endovascular repair for thoracic aortic aneurysm. These 68 patients, contained 47 men and 21 women, aged 46-94 years with a mean age of 69 $\pm$ 9.4 years old. Mean follow-up was 7.9 months (range: 1-24 months).

Endoleaks were detected in 38.2% (26/68) of patients. There were type I, type II, and type III endoleaks in 11.5% (3/26), 84.6% (22/26), and 3.9% (1/26), respectively. CT findings (Table 1, 2) revealed that all type II endoleaks contained tubular collection and 72.7% (16/22) of type II endoleaks had peripheral location. Only one patient had type III endoleak and appeared as non-tubular collection with central location. Shape and location of type I endoleak were nonspecific (Fig. 1).

Retrograde feeding vessels were depicted in all type II endoleaks. There were 11 (50%) endoleaks supplied by left subclavian artery (Fig. 2), five (22.7%) endoleaks supplied by intercostal artery (Fig. 3), three (13.6%) endoleaks supplied by two feeders, of which two endoleaks were supplied from the left subclavian artery combined with the left common carotid artery and another endoleak was supplied from the left subclavian artery combined with intercostal artery. The remaining 3 (13.5%) endoleaks were supplied each by other arteries, which were left common carotid artery, bronchial artery, and aberrant right subclavian artery.

Comparison between the patients with endoleak and without endoleak groups, no difference was detected regarding to the diameter ($p = 0.54$) and volume ($p = 0.71$) of the aneurysms. The length, number, and maximum tortuousity of the stent also

Table 1. Characteristic of leakage in each type of endoleak after TEVAR (n = 26)

Character of endoleak	Type I (n = 3)	Type II (n = 22)	Type III (n = 1)
Non-tubular collection	1 (3.8%)	-	1 (3.8%)
Tubular collection	2 (7.7%)	22 (84.6%)	-

Table 2. Location of leakage in each type of endoleak after TEVAR (n = 26)

Location of endoleak	Type I	Type II	Type III
Central	2 (7.7%)	3 (11.5%)	1 (3.8%)
Peripheral	-	16 (61.5%)	-
Combined	1 (3.8%)	3 (11.5%)	-

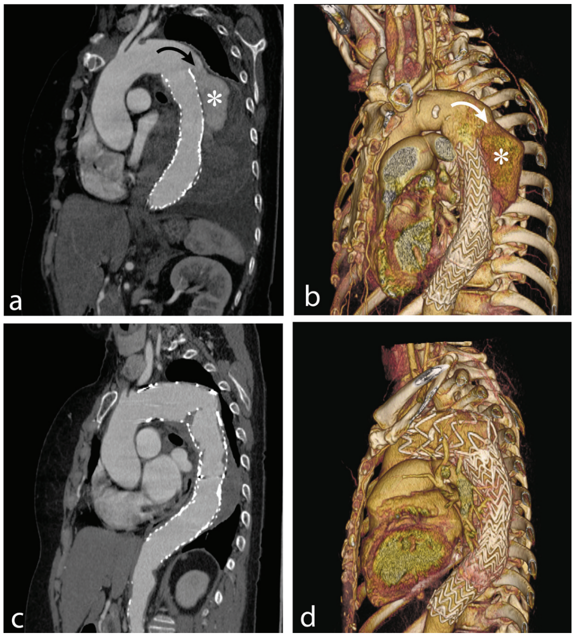

Fig. 1 Type I endoleak. Sagittal oblique CT image (a) and 3D volume rendering (b) of post TEVAR of descending aortic aneurysm show leakage of contrast media at proximal end of the stent graft (curved arrow) to aneurysmal sac (*), which is tubular shaped adjacent to supero-posterior aspect of the stent graft. After second session of TEVAR implantation, the sagittal oblique CT image (c) and 3D volume rendering (d) shows no residual endoleak from the proximal end of the stent graft

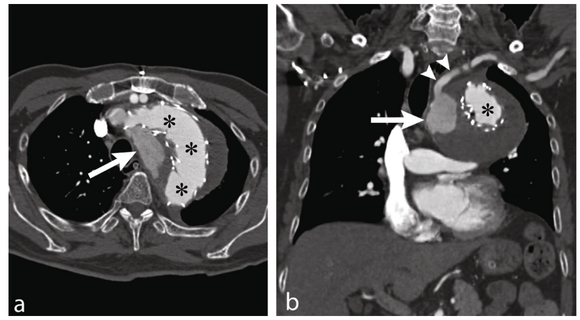

Fig. 2 Type II endoleak. axial (a) and coronal (b) CT images of the patient with aneurysm at aortic arch underwent TEVAR (*) with bypass grafts. Large amount of contrast leakage is detected in both central and peripheral (arrows), which is feeded from left subclavian artery (arrow heads)

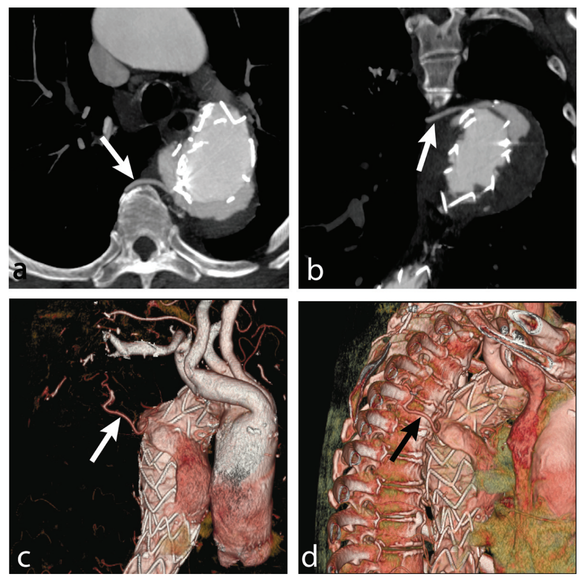

Fig. 3 Type II endoleak: axial (a) and coronal CT images (b) of patient with thoracic aneurysm underwent TEVAR demonstrate type II endoleak from adjacent intercostal artery. 3D volume rendering with (c) and without (d) bone removal in oblique view show also retrograde flow into aneurysmal sac

showed no differences between the two groups (p = 0.54, p = 0.98, p = 0.49, respectively).

Aneurysm location and stent graft landing zone were significantly different (p = 0.02, p = 0.03, respectively) that was endoleak usually occurred at proximal and mid aortic arch aneurysm (68.1%) whereas the descending thoracic aneurysm was an uncommon location for endoleak (31.9%).

Subgroup analysis in 20 patients who had completed follow-up CT images at 1, 3, and 6 months after operation, there were 14 patients with fusiform and six patients for saccular morphology. In fusiform morphologic subgroup, the average diameter, and volume of aneurysm in patients without endoleak was progressively decreased with time, especially in comparison between preoperative and 6-month follow-up images. On the contrary, type II endoleak in fusiform aneurysm, the average diameter, and volume of aneurysm were increase. For saccular morphologic subgroup, cases of with or without endoleak showed decrease in average diameter and volume of aneurysm (Table 3, 4).

The statistical correlation between average diameter and volume of aneurysm_showed moderate correlation (Fig. 4) with correlation coefficient 0.54, 0.60, and 0.63 at preoperative, 3 months, and 6 months CT images, respectively.

Table 3. Mean percentage change of aneurysm sac volume compared to preoperative measurement (n = 20)

Aneurysm morphology	Post-operation	Follow-up 3 months	Follow-up 6 months
Fusiform			
No endoleak (n = 9)	+4.9%	+0.6%	-6.9%
Type II endoleaks (n = 5)	+1%	+4.15%	+10.2%
Saccular			
No endoleak (n = 4)	+9.1%	-44.5%	-61.8%
Type II endoleaks (n = 2)	-27.4%	-75%	-77%

Table 4. Mean percentage change of aneurysm sac diameter compared to preoperative measurement (n = 20)

Aneurysm morphology	Post-operation	Follow-up 3 months	Follow-up 6 months
Fusiform			
No endoleak (n = 9)	-1.8%	-2.5%	-8.7%
Type II endoleaks (n = 5)	-3.4%	-1.2%	+2%
Saccular			
No endoleak (n = 4)	-3.7%	-13.1%	-13.1%
Type II endoleaks (n = 2)	0.0	-6.6%	-6.6%

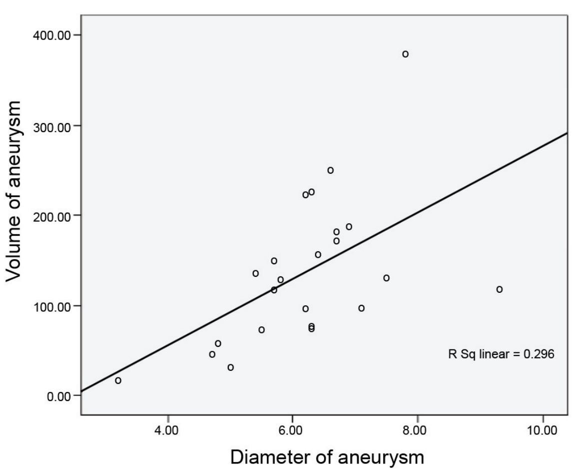

Fig. 4 A correlation of the linear relationship between volume and diameter of aneurysm was made using Pearson's correlation at 6 months follow-up after TEVAR. The correlation coefficient is about 0.63

Discussion

Endoleak occurrence was the significant indicator for predictive outcome of thoracic aortic aneurysm treated with TEVAR. The prior literature[9] reported that endoleak after any endovascular treatment of aortic aneurysms occurs in 3-44% of patients. The incidence of endoleak after TEVAR was also in the wide range of 5% to 30%(10-12). Parmer et al(12) showed there was a 24% incidence rate of endoleak in a series of 105 patients treated for thoracic aneurysm. Another recent study analyzed by Piffaretti et al(13) published a 14.7% endoleak in 61 patients underwent TEVAR. The present study showed that endoleaks after TEVAR were occurred in 38.2% composed of type I, II, and III endoleaks in 11.5%, 84.6%, 3.9%, respectively. Contrary to the data of Parmer (type I 40%, type II 35%, and type III 20%) and Piffaretti (type I 77.8% and type II 22.2%). The type I endoleak was due to technical failure, which was leakage of blood from the proximal or distal end of stent graft to aneurysm, whereas type III endoleak was due to fabric tears or disruption of the stent graft (device failure). The present study indicated that the higher incidence of endoleak was due to high incidence of endoleak type II, which was retrograde flow from the left subclavian artery, small intercostal or bronchial branches of the aorta.

Type II endoleak was supposed to be a channel-like tubular shape between the aortic wall and stent graft. A tubular contrast material collection located at or near the aortic wall provided indirect evidence of a type II endoleak(14). In the analysis of Chernyak et al(8) to classify CT findings of endoleak shape in 39 patients who had an endoleak after endoaortic graft implantation for treatment of abdominal aortic aneurysm, according to the characteristic of leakage, the authors found the similar result that peritubular collection and peripheral location were more common in type II endoleak than in type I or type III endoleak.

According to the finding that most common location of the aneurysms that had endoleak in the present study were located at aortic arch, thus the type II endoleak could be arising from retrograde flow from left subclavian artery (Fig. 2). In the authors' institute, debranching of left subclavian artery technique was not routinely performed. Thus, subsequent left subclavian artery revascularization occurred that caused type II endoleak. This endovascular treatment without debranching technique was considered to be the main factor for high incidence of endoleak especially type II endoleak. Besides the left subclavian artery, the other vessels that could supply the aneurysm were left common carotid, intercostal, and bronchial arteries (Fig. 3). In the present study, one patient with aortic arch aneurysm had aberrant right subclavian artery and endoleak was supplied by this vessel.

In the present study, the factors that had statistically significant differences between the group of patients who developed endoleak and those who did not find endoleak were location of the aneurysm and landing zone. Aneurysms at aortic arch were associated with higher endoleak occurrence whereas, aneurysms at the descending aorta were associated with lower occurrence ($p < 0.02$). No endoleak was detected in the aneurysm treated by stent graft with landing zone at descending aorta. The findings were supported by the study of Piffaretti et al[13].

EVAR has become an alternative to open surgery in patients with abdominal aortic aneurysm. Follow-up imaging to detect complication, aneurysm, and endograft morphology was necessary. Volumetric analysis has been advocated as a tool to monitor EVAR, with volume regression being the most common finding after successful EVAR[15]. Although the changes of aneurysm volume and diameter after EVAR was previously described[3,15,16], less is known about aneurysm changes after TEVAR. In the present study, the authors found a continuous increase in volume of fusiform aneurysm with endoleak patients across the entire follow-up duration. Lack of volume regression was suspected due to continued pressurization within the aneurysmal sac by endoleak. For fusiform aneurysm without endoleak, the volume of aneurysm was increased in the initial follow-up within one month after repair, whereas the diameter was decreased. The increased volume of aneurysm in initial follow-up was possibly due to measurement technique, which included the stent graft. However, on follow-up image at 6 months exhibited volume and diameter regression. This phenomenon was the same experience as the present study in a series of 177 patients with abdominal aortic aneurysm who underwent endovascular treatment published by Lee et al[3]. In the series of saccular morphology of aneurysm, the authors found a difference. Volume and diameter of two patients with type II endoleak were decreased during follow-up. The possible factor was associated with the retrograde feeding vessels supplying the aneurysm that were from bronchial and intercostal arteries. These vessels were smaller than the left subclavian artery and had minimal pressure to the aneurysmal sac. However, the present study was limited due to the small number of patients with saccular aneurysm who presented endoleak.

In the present study, the authors used maximum diameter in a single cross-section image of aneurysmal sac to follow-up the changes of aneurysm size from the fact that any change in maximal diameter of a sphere resulted in a volume change proportional to the cube of this diameter[16]. However, an analysis of relationship between volume and diameter measurement of the aneurysmal sac at each follow-up periods demonstrated moderate statistical correlation between two techniques (Fig. 4). The correlation was not exactly in linearity (R square = 0.296) but still had the statistical correlation. This finding yielded the radiologists to estimate the changing of aneurysm size in routine practice by measuring the cross-sectional diameter of aneurysm.

The limitation of the present study was its retrospective design. A second limitation was volumetric analysis technique which aorta covered by stent graft was included in the calculation. The technique could cause overestimation of the aneurysmal sac volume. Treatment and outcome of each type of endoleaks were not discussed. Another limitation was the duration of the follow-up period, which evaluated the follow-up images until 6 months after procedure, the long-term outcome in patients undergoing stent graft implantation was still uncertain and should continue to be evaluated.

Conclusion

Follow-up images with CT angiography are useful for detection and characterization of endoleaks.

Most of type II endoleaks show peritubular shape of contrast pooling and locate at periphery. Patients with type II endoleak after thoracic endovascular aortic repair tend to continue to have sac expansion without decreasing in diameter and volume of aneurysmal sac.

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การศึกษาการรั่วซึมภายหลังการรักษาหลอดเลือดแดงช่องอก ด้วยวิธีการสอดท่อหลอดเลือดเทียมแบบที่มีโครงค้ำยัน โดยภาพเอกซเรย์คอมพิวเตอร์หลอดเลือด

อารียา ธนสุนทรฤกษ์, จิตรลัดดา วะศินรัตน์, ทนงชัย สิริอภิสิทธิ์, วรวงศ์ ศลิษฏ์อรรถกร

วัตถุประสงค์: *ศึกษาอัตราการรั่วซึม และลักษณะของการรั่วซึมภายหลังการรักษาหลอดเลือดแดงช่องอกด้วยวิธีการสอดท่อหลอดเลือดเทียมแบบที่มีโครงค้ำยันโดยใช้การตรวจด้วยเอกซเรย์คอมพิวเตอร์*

วัสดุและวิธีการ: *ผู้ป่วยที่ได้รับการรักษาหลอดเลือดแดงช่องอกด้วยวิธีการสอดท่อหลอดเลือดเทียมแบบที่มีโครงค้ำยันในช่วง สิงหาคม พ.ศ. 2549 จนถึง ธันวาคม พ.ศ. 2551 จำนวน 68 ราย เป็นผู้ป่วยชาย 47 คน และผู้ป่วยหญิง 21 คน ค่าอายุเฉลี่ยเป็น 69 $\pm$ 9.4 ปี ภาพเอกซเรย์คอมพิวเตอร์ที่ได้จากการตรวจผู้ป่วยดังกล่าว ได้นำมาใช้ศึกษาอัตราการรั่วซึมและลักษณะของการรั่วซึม*

ผลการศึกษา: *พบการรั่วซึมในผู้ป่วย 26 ราย (38.2%) แยกได้เป็น แบบที่ 1, 2 และ 3 เป็นจำนวน 3 ราย (11.5%), 22 ราย (84.6%) และ 1 ราย (3.9%) ตามลำดับโดยการรั่วซึมมักจะพบแบบที่ 2 มากที่สุดซึ่งลักษณะการรั่วซึมพบอยู่ที่ขอบด้านนอกของหลอดเลือดแดงที่โป่งพอง ในกลุ่มที่มีการรั่วซึมแบบที่ 2 พบผู้ป่วย 11 ราย (50%) มีการรั่วซึมมาจากหลอดเลือดแดง subclavian ข้างซ้าย ซึ่งในจำนวนนี้มีผู้ป่วยจำนวน 20 ราย ได้รับการเฝ้าติดตามผลที่ระยะเวลา 1, 3 และ 6 เดือน ซึ่งภาพเอกซเรย์คอมพิวเตอร์จากผู้ป่วยกลุ่มนี้นำมาใช้ศึกษาการเปลี่ยนแปลงของปริมาตร และขนาดเส้นผ่าศูนย์กลางของหลอดเลือดโป่งพอง*

สรุป: *การตรวจติดตามผลการรักษาด้วยการใส่ลวดค้ำยัน ที่มีผนังหุ้มในผู้ป่วยที่มีหลอดเลือดแดงใหญ่โป่งพองมีประโยชน์ในการตรวจพบการรั่วซึม การรั่วซึมที่เกิดขึ้นมักจะเป็นชนิดที่ 2 มีลักษณะเป็นการรั่วซึมที่อยู่ใกล้ ๆ กับหลอดเลือดแดงโป่งพอง การวัดขนาดหลอดเลือดแดงในกลุ่มผู้ป่วยที่มีการรั่วซึมพบว่าการเปลี่ยนแปลงของค่าปริมาตรและเส้นผ่าศูนย์กลางของหลอดเลือดแดงโป่งพองไม่มีนัยสำคัญทางสถิติ*