I. Introduction

Non-obstructive general angioscopy (NOGA) is a novel technique that allows visualization of the inner aorta. Dual infusion method improves the visual field and the use of an Ikari-L guiding catheter allows easy access to the aorta, enabling NOGA of not only the coronary artery but also the aorta. Imaging techniques such as computed tomography angiography (CTA), magnetic resonance, and transesophageal echocardiography have been used to evaluate the aorta and the findings are usually confirmed based on pathology. NOGA has a spatial and temporal resolution superior to these techniques, detecting various types of spontaneous ruptured aortic plaques (SRAPs) and injuries. SRAPs detected using NOGA are not comparable to those detected using CTA. NOGA can also demonstrate subintimal changes and blood flow through the aortic wall. Although aortic angioscopy is yet at its dawn, several case reports have showed its ability to decode aortic dissection pathogenesis and to evaluate the merits and demerits of stent graft implantation. NOGA is a unique invasive modality to visualize the inner aorta and to sample SRAPs. NOGA is an epoch-making modality that can be used to simultaneously evaluate the arterial and venous systems.

KEY WORDS: aorta, non-obstructive general angioscopy, spontaneous ruptured aortic plaques

Spontaneous Ruptured Aortic Plaques and Injuries Detected using Non-obstructive General Angioscopy

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Aortic angioscopy using non-obstructive general angioscopy (NOGA) is a novel, video-based technique that allows visualization of the inner aorta. Dual infusion method improves the visual field and the use of an Ikari-L guiding catheter allows easy access to the aorta, enabling NOGA of not only the coronary artery but also the aorta. Imaging techniques such as computed tomography angiography (CTA), magnetic resonance, and transesophageal echocardiography have been used to evaluate the aorta and the findings are usually confirmed based on pathology. NOGA has a spatial and temporal resolution superior to these techniques, detecting various types of spontaneous ruptured aortic plaques (SRAPs) and injuries. SRAPs detected using NOGA are not comparable to those detected using CTA. NOGA can also demonstrate subintimal changes and blood flow through the aortic wall. Although aortic angioscopy is yet at its dawn, several case reports have showed its ability to decode aortic dissection pathogenesis and to evaluate the merits and demerits of stent graft implantation. NOGA is a unique invasive modality to visualize the inner aorta and to sample SRAPs. NOGA is an epoch-making modality that can be used to simultaneously evaluate the arterial and venous systems.

KEY WORDS: aorta, non-obstructive general angioscopy, spontaneous ruptured aortic plaques

I. Introduction

Non-obstructive general angioscopy (NOGA) is a novel technique to evaluate aortic atherosclerosis and injuries1). Aortic atherosclerosis is predictive of future adverse cardiovascular events; thus, its evaluation is essential to prevent these events2–4). Computed tomography (CT) has been considered the gold standard for evaluating aorta, and the findings obtained with CT have been confirmed by autopsy studies. However, both CT and pathology have limitations. Calcifications are easy to quantify and constitute a good marker for atherosclerosis of coronary artery and aorta. However, their representation of atherosclerosis is partial and indirect2, 3). CT angiography (CTA) has limited spatial resolution, up to 230 μm of the next-generation CT5, 6). CTA may provide static grayscale images and even four-dimensional images. In the absence of irregularities, intimal plaque or injuries cannot be demonstrated by CT due to the partial-volume effect. Although CT number may help distinguish between calcified and non-calcified plaques7), there is no unique number of thrombi on CT to distinguish non-calcified plaques. One alternative is to measure aortic wall thickness and plaque burden in specific slices using magnetic resonance imaging4). However, given that atherosclerosis is usually not evenly distributed in the aorta, partial analysis is unlikely to reflect the status of the whole aorta. Although transesophageal echocardiography provides live images, those are converted into grayscale images. Moreover, transesophageal echocardiography cannot cover the entire aorta, making it difficult to identify the precise position of the aorta. Autopsy studies provide static images, in which the plaques and proteins may be degenerated and cholesterol crystals may be lost due to formalin, xylene, and ethanol used during standard staining preparations8). NOGA successfully identifies SRAPs and injuries and allows screening of the whole aorta. NOGA’s spatial resolution is 100 μm. Spatial and temporal resolution of NOGA are superior to CTA and transesophageal echocardiography. NOGA provides direct images of both intimal and subintimal images.

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Review Article
II. Applying NOGA to the aorta

NOGA is a technology used to screen the inner aspect of vessels regardless of their size. It can simultaneously screen the coronary\(^9\), renal\(^10\), and pulmonary\(^11\) arteries and the aorta\(^12, 13\). Initially, this technology was used to analyze coronary artery plaques and stents\(^9, 14\). The visual field is obtained by injecting a transparent fluid into the gap between the probing catheter and the fiber. The grade of visual field is negatively correlated with large vessels (>4 mm), bifurcation, vessels with a sharp angle (minimal degree ≤ 120°), in-stent, and the distal border of stent, whereas it is positively correlated with significant stenosis (≥75%) and significantly covered stents\(^15\). A clear visual field can also be obtained by injecting the transparent fluid into the gaps between the probing catheter and a guiding catheter (dual infusion method)\(^15\).

The application of this technique was expanded to the aorta for two reasons: first, the dual infusion method improves the visual field in larger vessels, such as the aorta; second, an Ikari-L (IL) guiding catheter can easily access the aorta\(^16, 17\). IL guiding catheters with soft tips can easily wedge both sides of the coronary artery\(^16\) and reach any part of the aorta. Initially, atherosclerotic changes in the coronary artery were evaluated using a 5- or 6-point scale, according to the intimal yellowness and existence of mural thrombi\(^18, 19\). Dual infusion allows a precise characterization of ruptured plaques and injuries as well as application of NOGA to larger vessels, such as the aorta.

III. Spontaneous ruptured aortic plaques detected using NOGA in patients having or suspected to have coronary heart disease

Angioscopic findings are superior to those of CTA and intravascular ultrasound (IVUS) because they can demonstrate protruding or mobile plaques\(^1\). Various types of SRAPs have been detected (Fig. 1)\(^1, 12, 13, 20–24\). The normal aortic intima is white with a smooth surface (Fig. 2A). Puff ruptures are defined as white or white-yellow puff-like materials, which can easily blow out (Fig. 2B)\(^1, 13\). A chandelier appearance indicates an intimal change, which is glistening against light from the tip of the angioscopic fiber catheter, wriggling but not blown out (Fig. 2C)\(^1, 13\). A puff–chandelier rupture is a mixture of puff rupture and chandelier appearance (Fig. 2D)\(^1, 12\). The puff–chandelier rupture comprises atheromatous materials, fibrin, calcification, and macrophages. The atheromatous materials mainly comprise cholesterol crystals. Puff ruptures are not easily sampled and may be composed mainly of fibrin and less of atheroma and cholesterol crystals, unlike puff–chandelier ruptures. In a study of 324 patients having or suspected to have coronary artery disease, 80.9% had SRAPs\(^12\). The median length and width of the SRAPs are 254 μm and 258 μm, respectively. The smallest component was free monolayer cholesterol crystals, measuring 40 μm and 30 μm in length and width, respectively.
IV. Spontaneous aorta injuries detected using NOGA in patients having or suspected to have coronary heart disease

The aorta may present with several types of spontaneous injuries. “Strawberry jam” appearance is a condition involving the adherence of red thrombi to the surface of the aorta, which looks like strawberry jam. It is not ulcerative and can never be washed out by the transparent liquid infusion during NOGA (Fig. 3A). “Cotton candy” appearance\(^{13,20}\) is a condition that involves the deposition of solid white or red materials, which are not mobile (Fig. 3B). Erosive lesions below the medial aortic wall and angiographically observed ulcerations penetrating the internal elastic lamina and the media of the aortic wall are commonly detected (Fig. 3C). Fissures are defined as elongated clefts, or tears (Fig. 3D), and flaps are defined as partially detached pieces of tissue, which wave or flutter (Fig. 3E)\(^{1,13,23}\). A peeled intima is an intima peeled at a small area (Fig. 3F)\(^{22}\).

V. Subintimal change of the aorta detected using NOGA in patients having or suspected to have coronary heart disease

NOGA can demonstrate subintimal changes in the coronary artery and aorta besides intimal changes. Injuries such as intrasistent hematoma\(^{25}\) or dissection\(^{26}\) may occur after coronary stent implantation. NOGA reveals active subintimal bleeding at the edge of the implanted coronary stent\(^{27}\). The blood flows below the intima because it never blows out of the lumen. Spontaneous subintimal bleeding is revealed by NOGA (Fig. 4A and Fig. 4B). Subintimal bleeding can be demonstrated in a thrombosed acute aortic dissection with ulcer-like projections\(^{28}\). Subintimal bleeding is not communicated to the aortic flow; its direction is different from that of the aortic flow, and it occurs as a laminar flow.

VI. Blood flow through the aortic wall

Blood flow through the aortic wall due to SRAPs and injuries in patients having or suspected to have coronary artery disease can only be revealed using NOGA. Blood flow from the aortic wall to the outside vessels is common. In such cases, the adequacy of the word “bleeding” is arguable because blood flow from the aortic wall to the lumen has not been reported. Bleeding may be detected from fissures (Fig. 4C)\(^{29}\). Fissures, fissure bleeding, and flaps are detected in patients who are not clinically diagnosed with aortic dissection. Furthermore, CTA findings are not correlated with the angiographically detected fissures (Fig. 3D), fissure bleeding (Fig. 4C), and flaps (Fig. 3E). Intramural bleeding is bleeding toward the lumen, which, after 2 years, can form a cave\(^{22}\). Intramural bleeding might be the beginning of aortic plaque rupture, and it forms a cave after the plaque component is removed, resulting in a loft appearance\(^{22}\).

VII. Aortic angioscopy in clinical cardiology

NOGA can be applied to the aorta in several clinical settings. Initially, the distribution of aortic SRAPs and aortic injuries were
SRAPs are dominant in the infrarenal abdominal artery, suprarenal abdominal artery, and aortic arch. The number of SRAPs positively correlated with old age, hypertension, low-density lipoprotein cholesterol, smoking history, and coronary heart disease, whereas it negatively correlated with high-density lipoprotein cholesterol. SRAPs were found to be continuously located in a patient with shaggy aorta, which is associated with stroke after thoracic and abdominal endovascular aneurysm repair. Intimal changes immediately after thoracic endovascular aortic repair were evaluated in a patient with saccular aneurysm at the distal aortic arch. A ruptured plaque with mixed thrombi was found at the anterior aortic wall, adjacent to the bare stent graft.

Aortic injuries in patients with acute and chronic aortic dissection have been reported. The underlying etiology of acute aortic dissection is often an atherosclerotic disease. Angioscopic findings include atherosclerotic changes. Plaque rupture involves the disruption of the aortic intima and the protrusion of plaque contents into the vessel lumen. Moreover, fissure bleeding that was thought to be an entry has been demonstrated. Active laminar flow from low-density areas was revealed by CTA. Low-density-type aortic dissection might be an accurate term because the area is not thrombosed. Following stent graft implantation of an aneurysmal change after acute aortic dissection, NOGA revealed blood flow over the graft, potentially from an endoleak, which might be related to a partial stent graft injury. The aortic valve was successfully visualized in a patient with aortic stenosis. This information might support transcatheter aortic valve implantation strategies.

**Fig. 4**
A: Subintimal bleeding. The red area changes. (arrows) The flow is inconsistent with intimal flow.
B: Intramural bleeding. The red area does not change.
C: Fissure bleeding.

**Fig. 5**
A: A single image of puff rupture. Although the plaque seems mobile, this cannot be clearly demonstrated.
B: A set of same plaque. The puff plaque was observed to change shape. Plaques shown as * and # were same position among them.
VIII. Features of NOGA compared with other imaging modalities

IVUS, optical coherence tomography (OCT), and monorail-type angioscopy are used to visualize the coronary artery. These techniques may be run parallel to the inner vessel along with a 0.014-inch guidewire, using the monorail method. In general, IVUS and OCT signals reach only 1-cm depth and cannot reach the aortic wall. Monorail-type angioscopy does not provide a wide visual field, covering approximately 3 cm of the aortic diameter. Occlusion-type angioscopy is not safe, as it can provoke iatrogenic organ ischemia\(^1\). Therefore, it is currently unavailable. A balloon is used for coronary artery occlusion; however, it is difficult to occlude the aorta. NOGA is safe because catheter can be placed in every direction inside the aorta using an IL guiding catheter\(^2\). NOGA can detect dynamic intimal and subintimal changes in the same lesion. IVUS and OCT may miss fine changes while passing over a lesion in a few seconds. NOGA may provide the systemic atherosclerotic information on coronary arteries and aorta in a single session.

IX. Pitfalls of angioscopic demonstration

Angioscopy is a video-based imaging technique. A single image is not necessarily sufficient for interpretation. (Fig. 5A) One angioscopic image, instead of a video, tends to be misunderstood due to low quality or being out-of-focus. A set of continuous images is of advantage. (Fig. 5B) The aorta can move by pulsation, and maintaining the same position can be difficult. To show the aorta’s wide range, a connection of continuous images is effective (the caterpillar method)\(^3\). (Fig) The image series resembles a caterpillar because the catheter is rotated inside the cylinder-shaped aorta.

X. Perspective

Subclinical asymptomatic plaques accumulated by SRAPs might lead to organ dysfunction. How atherosclerosis-related aortic injury leads to acute aortic syndrome remains unknown. Data accumulation from multicenter studies using NOGA to clarify the pathogenesis of embolic diseases and aortic diseases is desired. NOGA is an epoch-making sole modality to evaluate arterial system, comprising coronary artery, aorta, and peripheral arteries, and venous system, comprising veins of lower extremities, inferior vena cava, and pulmonary veins, in a single session.

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