의학석사 학위논문

상장간막 동맥 박리 소실과 관련된 새로운 예후인자

New predicting factors associated with resolution of SMA dissection

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Abstract

Background: Computed tomography (CT) is the gold standard for assessing mesenteric arteries and is widely used for diagnosing and monitoring superior mesenteric artery (SMA) dissection. However, its rarity and the typically benign clinical course of SMA dissection limit the understanding of its long-term surveillance.

Purpose: This study aimed to evaluate the long-term radiologic prognosis of SMA dissection using data from a single center.

Materials and Methods: This retrospective study included patients diagnosed with SMA dissection between January 2012 and December 2021. We reviewed all CT images, classifying them according to the modified Sakamoto classification, and we assessed morphological changes in the dissections over time. The relationship between the radiologic prognosis of the dissection flap and clinical variables was also investigated.

Results: The study included 50 patients with symptomatic SMA dissection and follow-up CT images; the mean age was 54.0±9.3 years, and 44 were men. Complete resolution was observed in 34% of patients. Current smoking was inversely associated with complete resolution (odds ratio [OR], 0.107; 95% confidence interval [CI]: 0.019, 0.596; P=.011) in univariable analysis. Multivariable analysis indicated both a history of smoking and the presence of thrombi in the false lumen as associated with complete resolution (OR, 0.087; 95% CI: 0.014, 0.520; P=.011; and OR, 31.707; 95% CI: 1.265, 794.465; P=.035, respectively). In the subgroup analysis of patients with thrombosis in the false lumen, no significant association was found between Hounsfield unit measurements and complete resolution (OR, 0.995; 95% CI: 0.944, 1.050; P=.867).

Conclusion: Acute SMA dissection featuring a thrombosed false lumen is associated with favorable radiologic outcomes.

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Keywords: CT angiography is gold standard modalities in diagnosis, classification, and follow-up of SMA

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Introduction

Superior mesenteric artery (SMA) dissection is regarded as a relatively benign condition according to recent literature (1–3). The latest consensus recommends conservative treatment as the initial management for SMA dissection without bowel ischemia, accompanied by short-term follow-up for patients with stable disease (4,5). The rarity of the disease and the relatively small scale of prior studies, however, contribute to a lower level of evidence.

Computed tomography (CT) angiography is pivotal in diagnosing SMA dissection (6,7); it is also a key tool for follow-up surveillance, as noted in the relevant European guidelines (8). Despite this, data on the long-term radiologic outcomes of SMA dissection remain scarce (9).

This study aimed to assess long-term radiological outcomes and identify prognostic factors associated with SMA dissection by analyzing a decade's worth of patient data from a single center.

Materials and Methods

Study population

We conducted a retrospective review of patients who visited a tertiary medical center between January 2012 and December 2021. Patients with the diagnostic code for "aneurysm or dissection of other arteries" as per the Korean Standard Classification of Disease were identified for inclusion in this SMA dissection study. We excluded patients with diseased arteries other than the SMA, SMA dissection diagnosed prior to 2012, dissection flaps originating in the aorta and extending to the SMA, active/uncontrolled malignancies, or lack of follow-up imaging. Only those presenting with symptoms at the time of diagnosis were included so that the study focused on acute-onset SMA dissection. The Institutional Review Board of Asan Medical Center approved the study protocol (No. 2022-1033), waiving the requirement for written informed consent due to the retrospective study design..

Diagnosis and classification of SMA dissection

CT scans were used to diagnose SMA dissection. The initial CT images were evaluated to classify the SMA lesions according to the modified Sakamoto classification (10,11) (Fig 2). During follow-up, morphological changes were categorized into four subgroups (12–14): (1) complete resolution, or complete remodeling, indicating the dissection had resolved, and the arterial lumen was fully restored (15) (Fig 3); (2) partial remodeling, described as improvement in true lumen patency relative to dissection length, thrombosis, and reduction in true lumen diameter (Fig 4); (3) no change, where the dissection remained unchanged in consecutive imaging (Fig 5); and (4) negative remodeling, defined as a diminution in true lumen patency (Fig 6).

Clinical course of SMA dissection

The primary treatment for symptomatic SMA dissection involved bowel rest, hydration, pain management, and antihypertensive medication when necessary. Anticoagulation treatment decisions were made according to the preference of three vascular surgeons at the center, with most symptomatic patients receiving anticoagulants. Follow-up protocols varied based on dissection severity and physician discretion; typically, patients

underwent follow-up CT angiography (CTA) every 3 to 6 months. Stable patients could have anticoagulation/antiplatelet therapy discontinued and follow-up visit frequency reduced.

Data collection

Data were collected through a review of electronic medical records. We reviewed past medical histories, checking for conditions such as hypertension, diabetes, coronary artery disease, cerebrovascular disease, and other peripheral arterial diseases, and we collected other relevant data like smoking and alcohol consumption history. For classification and radiologic analysis of each dissection—including distance from the SMA ostium, false lumen patency, total length of the dissection flap, and branch involvement—all diagnostic CT images were meticulously inspected. Furthermore, all subsequent CT scans, regardless of their purpose, were evaluated to monitor for changes in SMA dissection morphology. When endoscopic ultrasonography (EUS) or other diagnostic imaging was performed, these findings were also reviewed.

CT Protocol and Measurement of Hounsfield Units

CT scans adhered to a 110-kV protocol with automated tube current modulation, referencing a 52-mAs value. All CTA images underwent reconstruction using the ADMIRE (Advanced Modeled Iterative Reconstruction) technique at level 3. This method highlights our commitment to iterative reconstruction to enhance image quality while reducing radiation exposure. Hounsfield unit (HFU) measurements were taken with a preselected 2-mm2 region of interest at the thrombus's densest part. Density was measured five times on non-contrast axial images to avoid blooming artifacts, and the lowest recorded HFU value was noted.

Statistical analysis

Categorical and continuous variables were compared using the chi-square test and Student's t-test, respectively. Univariate and multivariate logistic regression analyses determined the association between complete resolution on CTA and clinical variables. Variables with $P < .1$ were included in the multivariate analysis, and relationships were expressed as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was acknowledged at $P < .05$. Analyses were conducted using SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY, USA).

Results

In this study, 671 patients were screened using the specified diagnostic code; of these, SMA dissection was identified in 97 patients. Application of the exclusion criteria led to the removal of 25 patients (Fig 1). Among the remaining 72 patients with SMA dissection and comprehensive electronic medical records, symptomatic SMA dissection was noted in 50. Baseline characteristics and medical history are detailed in Table 1. The cohort was predominantly male (88%, n = 44), with a mean age of 53.96 years. A history of current or past smoking was present in 58% of the patients, and 30% had hypertension.

Table 2 presents CT findings and clinical outcomes. The application of the modified Sakamoto classification revealed that classes III and IV were more common among patients with symptomatic SMA dissection. Eighty percent of patients (n = 40) had evidence of thrombosis in the false lumen. There were no significant intergroup differences in terms of the other anatomical factors. Ten percent of patients with symptomatic SMA dissection were managed conservatively, while 88% received anticoagulation or antiplatelet therapy. One patient underwent patch angioplasty of the SMA without small bowel resection, as there was no intraoperative evidence of bowel strangulation. Most patients experienced symptom relief, with only one patient (2%) reporting persistent chronic abdominal pain despite treatment. The mean interval between the initial diagnosis and the last CT scan was 31.7 months. For those with symptomatic SMA dissection, 34% achieved complete resolution, 42% achieved partial remodeling, 18% had no change, and 6% experienced negative remodeling.

Univariable and multivariable analyses of complete remodeling in SMA dissection are summarized in Table 3. Initially, the univariable analysis indicated that current smokers were less likely to exhibit complete remodeling (OR, 0.107; 95% CI: 0.019, 0.596; P = .011). No statistical significance was found for factors such as sex, age, alcohol consumption, hypertension, diabetes, hyperlipidemia, coronary artery disease, or various anatomical characteristics. In the multivariable analysis, which included variables with P < .1 from the univariable analysis, the OR for current smokers was 0.087 (95% CI: 0.014, 0.520; P = .007), and the presence of thrombi in the false lumen had an OR of 31.707 (95% CI: 1.265, 794.465; P = .035).

EUS was performed on 27 patients to aid with treatment planning. There was no discernible difference between patients who underwent EUS and those with symptomatic SMA dissection in terms of CT classifications and prognosis (Supplementary Table 1). EUS findings showed six patients with flow in the false lumen; all had intact flow to the distal SMA. The patency

of the false lumen indicated by EUS was associated with subsequent complete resolution of the dissection flap on CTA (Supplementary Table 2). However, no association was found between stenosis and complete resolution nor between stenosis measurements by CTA and EUS (Supplementary Figure 1).

Discussion

CT is the gold standard for diagnosing and monitoring SMA dissection. However, due to the condition's rarity and generally benign nature, the correlation between CT findings and SMA dissection prognosis is not well defined. In our study, a thrombosed false lumen was significantly associated with complete resolution of the dissection (P = .035), while no such associations with the other investigated variables were ascertained.

SMA dissection classifications are derived from angiographic images and vary across systems. Sakamoto's classification, introduced in 2007, delineates SMA dissection into four types (10). Zerbib et al. later expanded this classification with types V and VI, encompassing aneurysmal dissection and partial or complete occlusion of the SMA, respectively (14). Yun's classification, another popular system, categorizes SMA dissection into three types based on flow in the false lumen and true lumen patency (13) and is known for its simplicity and comprehensiveness. Yet, all classification systems have inherent limitations in reflecting the full spectrum of anatomical and clinical correlations (16).

Yuan et al. observed that type I SMA dissections often remained unchanged during follow-up, but false lumen thrombosis frequently resulted in improvement (16). Other studies have noted that patients without false lumen thrombosis tend to experience no change or a negative resolution (17,18). Our focus was on patients with symptomatic SMA dissection exhibiting acute-onset abdominal symptoms. In those without small bowel ischemia who improved with conservative care, including anticoagulation, false lumen thrombosis predicted a higher chance of complete resolution.

We hypothesized that thrombi in the false lumen might help predict prognosis. A prior study at our center found an association between low thrombus density (lower HFU) on CT and thrombus regression or stability. However, in this study, we found no significant correlation between the HFU of thrombi within the false lumen and the complete resolution of the dissection flap. EUS findings performed on some patients to evaluate true lumen flow dynamics were not consistently associated with CTA or imaging prognosis.

The limitations of this study included its single-center design, potential biases, and a sample size that may be insufficient for robust statistical analysis. The univariable analysis involved Firth's penalized likelihood method due to sample constraints. Despite this, our 10-year study period allowed for a relatively large patient cohort compared with those of previous studies. Challenges in analyzing treatment-based outcomes arose from the retrospective design and the common use of antiplatelet therapy. Multicenter randomized trials are necessary to address these limitations. Nonetheless, our study's sample size for isolated SMA dissection was considerable, with a mean follow-up period of about 32 months. Future research can build on our findings to establish prognostic and follow-up protocols for SMA dissection.

In summary, our findings underscore a significant association between the presence of thrombosed false lumen in angiographic images and the likelihood of achieving complete radiological resolution among patients with symptomatic SMA dissection without bowel ischemia.

Figure 1. Flowchart of inclusion and exclusion of study population

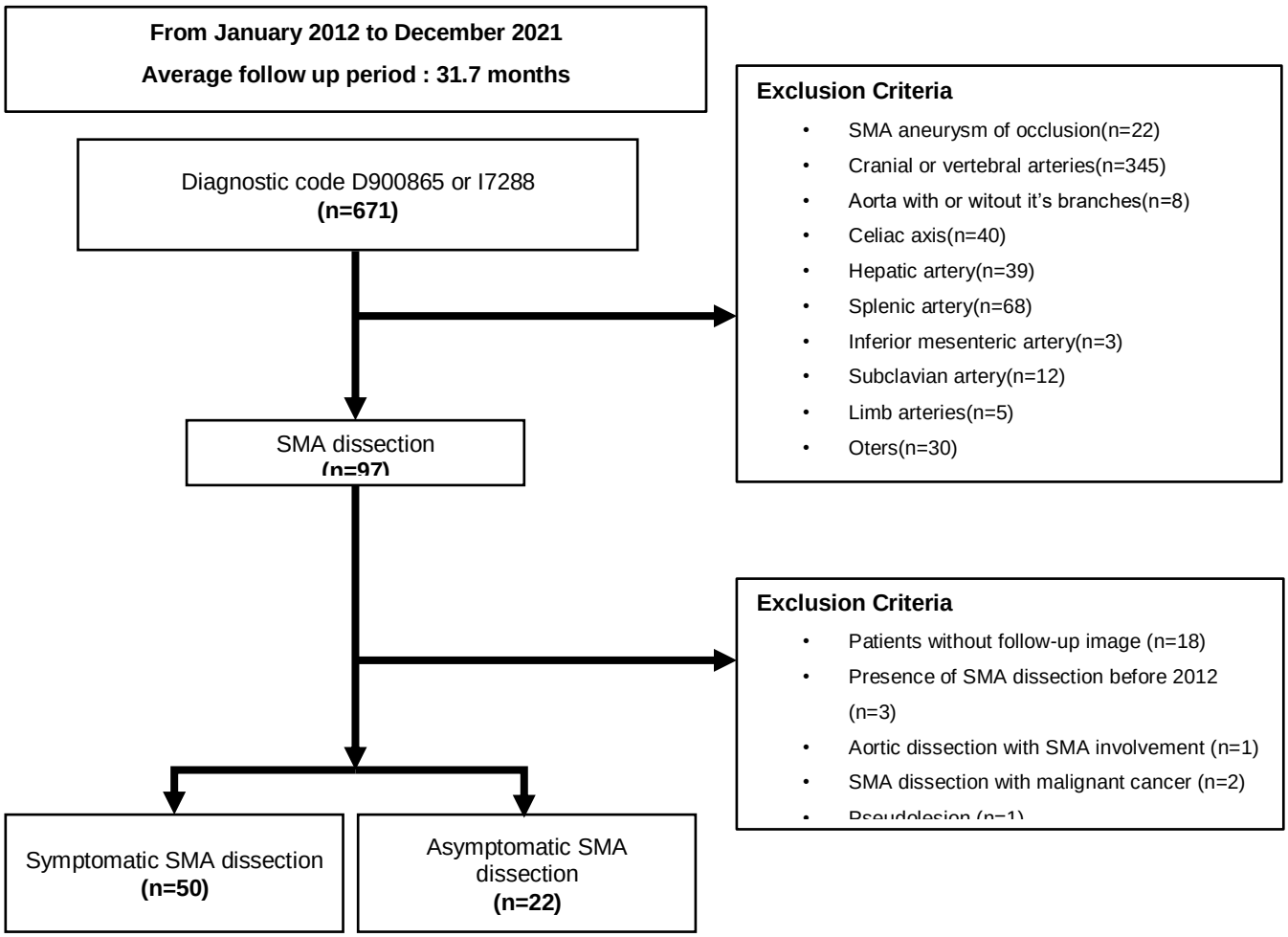
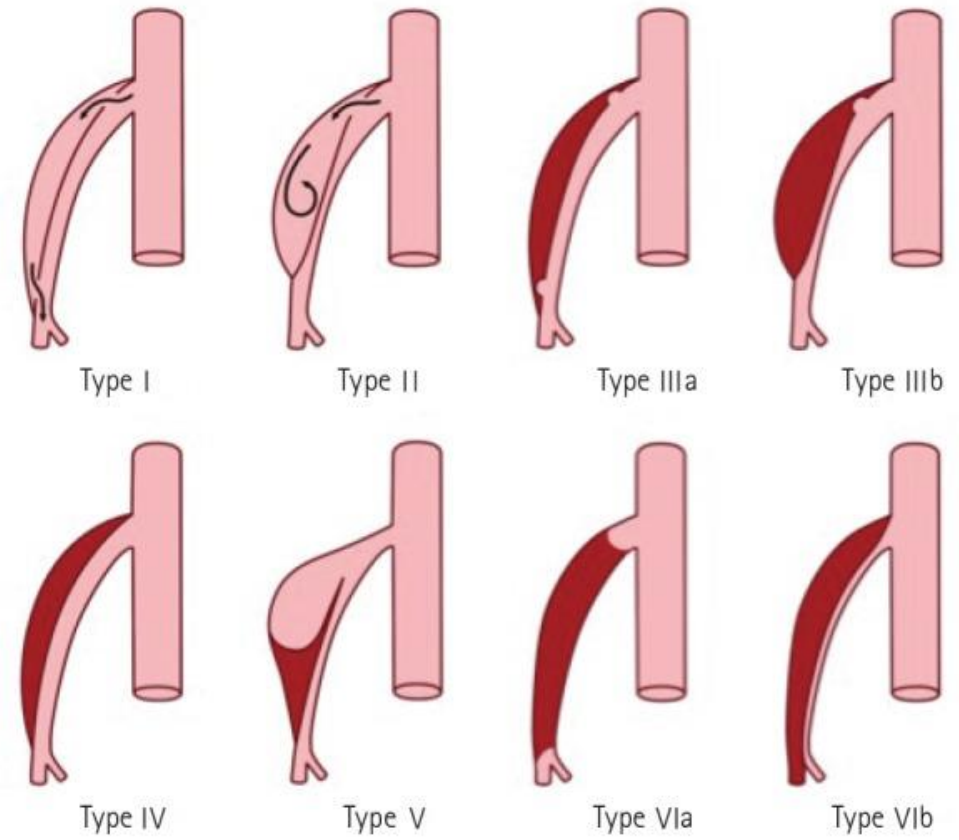


Figure 2. Modified Sakamoto's classification. Type I ~ type VI



Type I: patent false lumen with both entry and re-entry; Type II: 'cul-de-sac'-shaped false lumen without re-entry; Type III: thrombosed false lumen with an ulcer-like projection; Type IV: completely thrombosed false lumen with no ulcer-like projection; Type V: aneurismal dissection with stenosis of the distal part of the SMA; Type VI: total (VIa) or partial (VIb) thrombosis of the SMA. SMA: superior mesenteric artery[19].

Figure 3. Complete resolution of SMA dissection. (A) SMA dissection with thrombosed false lumen at initial diagnosis. (B) Fully resolved dissection after 15-mo follow-up

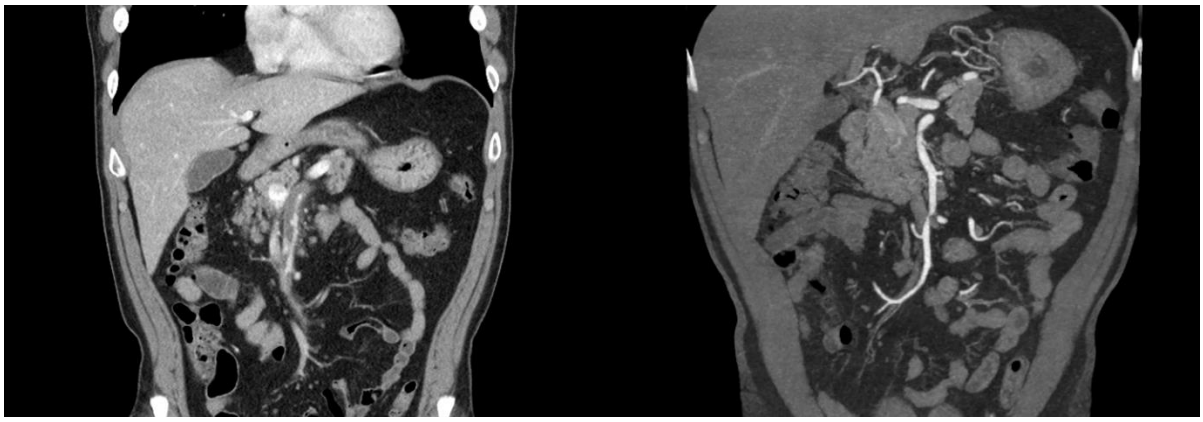


Figure 4. Positive remodeling of SMA dissection. (A) SMA dissection with long-segment, thrombosed false lumen at initial diagnosis. (B) Nearly improved but focal focal remnant proximal SMA dissection for 3-mo follow-up

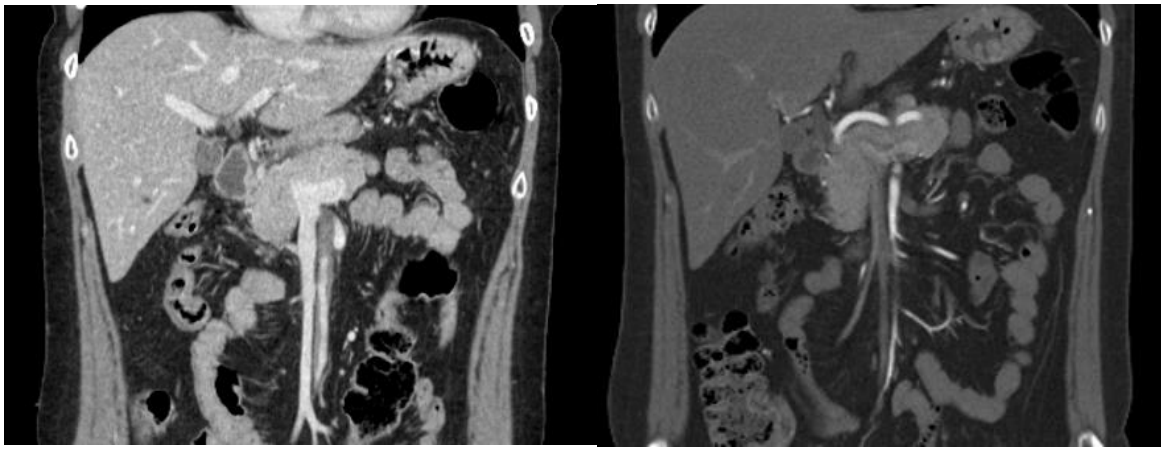


Figure 5. No-change of SMA dissection. SMA dissection at initial diagnosis (A) and 6 months of follow-up

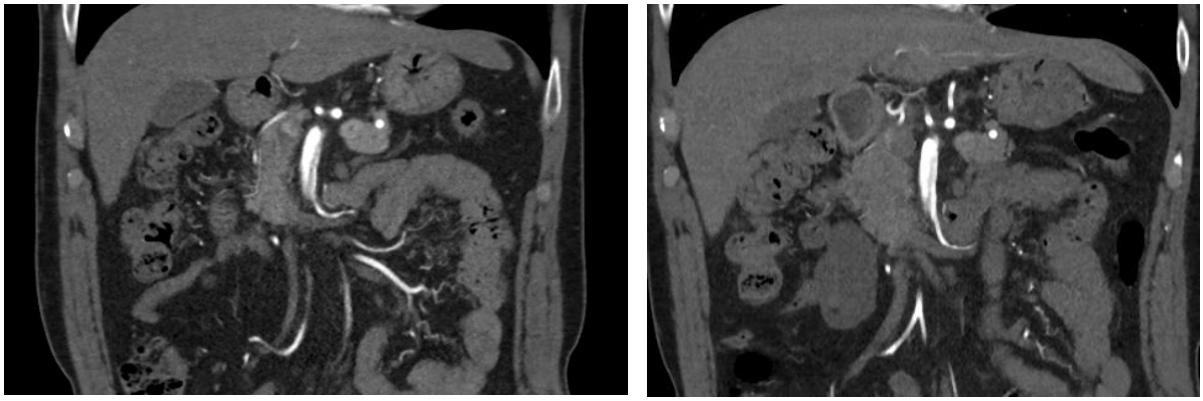


Figure 6. Negative resolution of SMA dissection. (A) Narrowed true lumen with thrombosed false lumen at initial diagnosis. (B) Improved luminal narrowing of true lumen in 3-mo follow-up. (C) Newly occluded branch of SMA in same period of follow-up

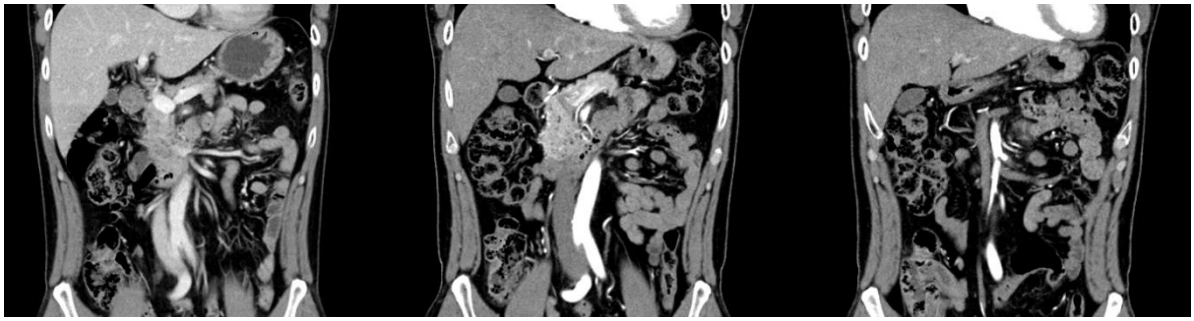


Table 1. Baseline characteristics of study population

	Symptomatic SMA dissection (n=50)
Male sex	44 (88%)
Age, years	53.96±9.331
Smoking history	
Current	16(32%)
Prior	13(26%)
Alcohol consumption	
Current	29 (58%)
Prior	2 (4%)
Hypertension	15 (30%)
Diabetes mellitus	2(4%)
Hyperlipidemia	5 (10%)
Coronary artery disease	2 (4%)
Cerebrovascular or peripheral arterial disease	0 (0%)
[a]Other	5 (10%)
Modified Sakamoto's classification	
I	6 (12.0%)
II	2 (4.0%)
III	13 (26.0%)
IV	25 (50.0%)
V	2 (4.0%)
VI	2 (4.0%)
Characteristics of dissection	

Distance from SMA ostium, cm	1.78 ± 1.97
Length of dissection, cm	6.52 ± 2.95
False lumen thrombosis	40 (80.0%)
Stenosis of true lumen, %	53.5 ± 23.4
Branch involvement	38 (76.0%)
Treatment	
Conservative	5 (10.0%)
Anticoagulation	43 (86.0%)
Antiplatelet	1 (2.0%)
Intervention	1 (2.0%)
Relief of symptom	49 (98.0%)
Radiologic prognosis	
Complete resolution	17 (34.0%)
Partial remodeling	21 (42.0%)
No change	9 (18.0%)
Negative remodeling	3 (6.0%)

[a]Other included any malignancies, viral hepatitis with or without liver transplantation, autoimmune disease, etc

Table 2. Univariable and multivariable analysis of complete remodeling in SMA dissection

	Univariable analysis			[a]Multivariable analysis		
	Odds ratio	95% CI	*P*-value	Odds ratio	95% CI	*P*-value
Male sex	4.769	0.775-29.339	0.092			
Age	1.017	0.956-1.083	0.591			
Smoking			0.018	1(ref)		
Current vs. none smoker	0.107	0.019-0.596	0.011	0.087	0.014-0.520	0.007
Prior vs. none smoker	0.225	0.048-1.063	0.060	0.134	0.025-0.717	0.019
Alcohol			0.382			
Hypertension	0.615	0.162-2.336	0.476			
Diabetes	2.000	0.117-34.096	0.632			
Hyperlipidemia	0.453	0.047-4.407	0.495			
Coronary artery disease						
Dissection characteristics						
Distance from SMA ostium	1.154	0.845-1.576	0.368			

Length of dissection	1.134	0.923-1.392	0.230			
False lumen thrombosis				31.707	1.265-794.465	0.035
Stenosis of true lumen	1.007	0.981-1.033	0.611			
Branch involvement	2.625	0.495-13.916	0.257			
Mean HFU	1.019	0.961-1.080	0.537			
Minimal HFU	0.995	0.944-1.050	0.867			

[a]Multivariable analysis was performed including variables with '*P*-value < 0.1' in univariable analysis, Backward elimination was doneAbbreviations:

CI: confidence interval

Supplementary table 1. Findings of CT angiography and EUS in Patients who underwent EUS, compared to patients with symptomatic SMA dissection

	Symptomatic SMA dissection (n=50)	Patients underwent EUS (n=27)
Modified Sakamoto's classification in CT angiography		
I	6 (12.0%)	2 (7.4%)
II	2 (4.0%)	1 (3.7%)
III	13 (26.0%)	7 (25.9%)
IV	25 (50.0%)	15 (55.6%)
V	2 (4.0%)	1 (3.7%)
VI	2 (4.0%)	1 (3.7%)
Radiologic prognosis in subsequent CT angiography		
Complete resolution	17 (34.0%)	10 (37.0%)
Partial remodeling	21 (42.0%)	13 (48.1%)
No change	9 (18.0%)	3 (11.1%)
Negative remodeling	3 (6.0%)	1 (3.7%)
Findings in EUS		
Flow through false lumen		6 (22.2%)
Degree of stenosis, %		70.1 ± 12.8
[a]Severe stenosis		????
Intact distal SMA flow		27 (100%)

[a]severe stenosis was determined by EUS findings including degree of stenosis and flow velocity;

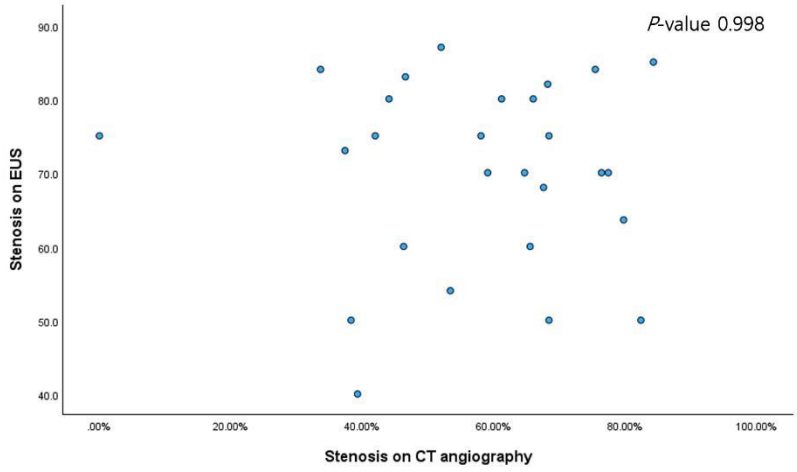
Abbreviations: EUS: endoscopic ultrasonography

Supplementary table 2. Comparison of EUS findings between the group with complete resolution and the group without complete resolution

	Complete resolution (n=10)	No complete resolution (n=17)	*P*-value
Flow through false lumen	0 (0.0%)	6 (35.3%)	0.033
Stenosis			
Degree of stenosis, %	66.4 ± 15.3	72.4 ± 10.9	0.246
Severe stenosis	5 (50.0%)	13 (76.5%)	0.159

Abbreviations: EUS: endoscopic ultrasonography

Supplementary figure 1. Scatterplot of degree of stenosis between CT angiography and EUS



Abbreviations: EUS: endoscopic ultrasonography

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국문요약

상부장간막동맥(SMA) 박리는 일반적으로 CT를 사용하여 진단됩니다. 그러나 이 질병이 드물고 비교적 양성 임상 경과를 가지고 있기 때문에 장기간의 추적 관찰에 관한 정보가 제한적인 상태입니다. 본 연구에서는 단일 센터의 경험을 기반으로 SMA 폐쇄의 장기적인 radiologic prognosis에 관련된 요인을 확인하고자 했습니다..

본 연구에는 2012년 1월부터 2021년 12월까지 상부장간막동맥(SMA) 박리로 진단받은 환자들이 포함되었습니다. 우리는 모든 사용 가능한 CT 영상을 면밀히 검토했으며, 이를 수정된 Sakamoto 분류에 따라 분류했습니다. 거기에 더해 추적 관찰 중에 박리부위의 형태학적 변화도 식별하고 radiologic prognosis와 임상 변수 간의 관계를 조사했습니다.

본 연구에 포함된 총 72명의 환자는 상부장간막동맥(SMA) 박리로 진단받았으며 추적 CT 영상이 있었습니다. 증상이 있는 상부장간막동맥(SMA) 박리 환자들은 초기 CT 영상에서 false lumen 내 혈전을 보이며 추적 영상에서 형태학적 변화를 경험하는 경향이 있었습니다. 초기 CT에서 false lumen thrombosis는 추적에서 영상의학적 완전소실과 관련이 있었으며, 다변량 분석에서 이를 확인했습니다.

혈전이 형성된 false lumen이 있는 급성 상부장간막동맥(SMA) 박리는 유리한 방사선적 전망과 관련이 있습니다. 알맞은 치료를 통한 증상 완화는 이러한 환자들에게 선호되는 예후를 제공하며 의사의 추적 관찰에 대한 결정에 정보를 제공합니다.