ABSTRACT

Objective: The concept of managing patients on the basis of culprit lesion characteristics is emerging. Atherosclerotic plaques are reported to be rare in young patients presenting with acute coronary syndrome (ACS). We aimed to assess culprit lesion characteristics in very young patients presenting with ACS by optical coherence tomography (OCT).

Methods: This was a prospective, single-center, open-label, observational study. Patients aged 35 years or less with ACS who underwent invasive coronary angiography and OCT were studied.

Results: Of the 43 patients, 22 (51.2%) had plaque rupture, 16 (37.2%) had plaque erosion, and five (11.6%) had no specific lesion character. Plaque was fibroatheromatous in 34 (79.1%) patients and fibrous in seven (16.3%). Plaque was not found in two (4.7%) patients; of these, one (2.3%) had left anterior descending coronary artery bridging, and one (2.3%) had intimal dissection without any plaque. Plaque rupture was more commonly associated with fibroatheromatous plaques, whereas plaque erosion was more commonly associated with fibrous plaque (p=0.010).

Conclusion: Although plaque rupture and plaque erosion occurred at the same rate as seen in patients of all ages, calcified nodule as a culprit lesion was not found in young patients. Majority of the patients had plaque rupture and plaque erosion with fibroatheromatous plaque, signifying the occurrence of established coronary artery disease in very young patients of Southeast Asia.

Keywords: acute coronary syndrome, atherosclerotic plaque, myocardial infarction, optical coherence tomography, ST elevation myocardial infarction

Introduction

Atherosclerosis is the most common underlying pathology in acute coronary syndrome (ACS) (1). Plaque rupture, the major mechanism for ACS, activates platelets and triggers the coagulation cascade leading to thrombosis which can potentially lead to ACS (2). Autopsy examinations have revealed the absence of plaque disruptions in 25% patients with ACS (3-6). This is suggestive of additional mechanisms leading to ACS, which include plaque erosions and calcified nodules (7). Differentiation of underlying mechanisms in ACS, namely plaque rupture, plaque erosion, and calcified nodule is not possible with coronary angiography owing to its inability to assess vessel wall pathology; and therefore, many patients undergo stent implantation irrespective of the underlying mechanism (8). This “one size fits all” strategy prevents exploration of the natural history of patients with different culprit lesions (4). Optical coherence tomography (OCT) overcomes this shortcoming (8-10).

OCT imaging of culprit coronary arteries in patients with ACS has been performed in a number of studies, and the results of plaque erosion and plaque rupture correlate with autopsy series (10, 11). Plaque rupture is associated with larger infarcts with large plaque burden, occluded culprit arteries, larger lipid burden, and larger thrombus burden with predominant red throm-
was explained. Written informed consent was provided by all the enrolled patients after the procedure. The study was performed in accordance with the Institutional Ethics Committee.

The study inclusion and exclusion criteria are illustrated in Figure 1. The study was conducted at a tertiary-care center in India.

In our study, culprit lesion characteristics in patients with ACS below 35 years of age showed that fibroatheromatous plaque was found in most of our patients (79.1%), and plaque erosion occurred in more than one-third (37.2%) of the study population, signifying the occurrence of established coronary artery disease in very young patients of the South Asia region.

**HIGHLIGHTS**

- In the very young South Asian population, the mechanism of acute coronary syndrome (ACS) is not yet completely understood.
- In our study, culprit lesion characteristics in patients with ACS below 35 years of age showed that fibroatheromatous plaque was found in most of our patients (79.1%), and plaque erosion occurred in more than one-third (37.2%) of the study population, signifying the occurrence of established coronary artery disease in very young patients of the South Asia region.

**Methods**

**Study design and patient population**

This was a prospective, single-center, open-label, and observational study conducted at a tertiary-care center in India. Patients aged 35 years or less in whom ACS was a triggered event were studied. All the patients underwent invasive coronary angiography, followed by OCT. The identification of the culprit lesion was made on the basis of coronary angiography, electrocardiography, or echocardiography. Tight lesions that prevented blood clearance by contrast were pre-dilated for plaque erosion or stent implantation (12, 13). Plaque erosion managed with thrombosuction and antiplatelet therapy alone demonstrated no clinical recurrences in 12 (33%) lesions at a median follow-up of two years (10). There is evidence for a similar response to intervention in both plaque rupture and erosion (13). Because of discrepancies in the aforementioned studies, large trials to address this issue are warranted. It remains unestablished if ACS with plaque erosion can be managed by alternate means and stenting can be deferred to reduce complications that are secondary to high thrombus burden (14). In this study, we have described culprit lesion characteristics in very young patients (15, 16) presenting with ACS by OCT.

**Atherosclerotic lesion morphology**

Lesion and reference segments were defined according to the International Working Group for Intravascular OCT Standardization and Validation (IWG-IVOCT) (17).

**OCT image acquisition**

The OCT images were acquired with a frequency-domain OCT system and the DragonFly catheter (Ilumien Optis, St. Jude Medical, St. Paul, Minnesota, USA). The automated pullback was performed at a speed of 20 mm/s to clear blood from the culprit artery by contrast injection.

Plaque rupture was defined as the presence of rupture or discontinuity in the fibrous cap. Plaque erosion was defined as the presence of an intact fibrous cap with attached thrombus, irregularity of the lumen of the culprit lesion in the absence of thrombus, or lesions with underlying plaque attenuated by thrombus. Lesions such as bridging in the left anterior descending coronary artery or intimal dissection, which did not meet any of the above criteria were categorized as others. Tissue characteristics of underlying plaque were also studied. Fibrous plaque was identified as a homogeneous plaque with high backscatter. Fibroatheromatous plaque was identified as low backscatter plaque with diffuse border and attenuation. Thin-cap fibroatheroma (TCFA) was defined as plaque with lipid content with the thinnest part of the fibrous cap measuring <65 µm. Red thrombus was identified by high backscatter and high attenuation. White thrombus was identified by high backscatter with low attenuation. Microchannels were defined as poor signal regions that were sharply delineated in multiple contiguous frames.

**Statistical analysis**

The Statistical Package for Social Sciences (SPSS; Chicago, IL, USA) program, version 26 was used for data analysis. Continuous variables were expressed as mean ± standard deviation and categorical variables as percentages. Categorical variables were compared with the chi-squared test or Fisher’s exact test. A p value <0.05 was considered statistically significant.

**Results**

**Baseline characteristics**

A total of 43 patients were included in this study. Of them, 18 (41.9%) were aged between 24 and 30 years, and 25 (58.1%) patients were aged between 31 and 36 years. More men (n=42; 97.7%) than women participated in the study. The most com-
mon risk factors were smoking (n=23; 53.5% patients), followed by tobacco chewing (n=17; 39.5% patients). Most common clinical presentation was STEMI in 31 (72.1%) patients and NSTEMI ACS in 12 (27.9%) patients. The baseline characteristics of the study population are demonstrated in Table 1.

Lesion characteristics
On coronary angiography, 36 (83.7%) patients displayed single-vessel disease. The culprit artery was left anterior descending coronary artery in 35 (81.4%) patients, right coronary artery in six (14.0%), and the left circumflex artery in two (4.7%) patients. The coronary culprit lesion was plaque rupture in 22 (51.2%) patients, plaque erosion in 16 (37.2%), and five (11.6%) had no specific lesion character. Plaque was not found in two (4.7%) patients; of these, one (2.3%) had left anterior descending coronary artery bridging, and the other (2.3%) had intimal dissection without any plaque. Plaque was fibroatheromatous in 34 (79.1%) patients and fibrous in seven (16.3%).

Table 1. Baseline characteristics of study population

| Characteristics                                      | Patients (n=43) |
|------------------------------------------------------|----------------|
| **Age**                                              |                |
| 24–30 years, n (%)                                   | 18 (41.9)      |
| 31–36 years, n (%)                                   | 25 (58.1)      |
| Male, n (%)                                          | 42 (97.7)      |
| **Risk factors**                                     |                |
| Smoker, n (%)                                        | 23 (53.5)      |
| Tobacco chewing, n (%)                               | 17 (39.5)      |
| Diabetes, n (%)                                      | 2 (4.7)        |
| Hypertension, n (%)                                  | 2 (4.7)        |
| Family history of coronary artery disease, n (%)      | 2 (4.7)        |
| **Diagnosis**                                        |                |
| ST-segment elevation myocardial infarction, n (%)    | 31 (72.1)      |
| Non-ST-elevation acute coronary syndrome, n (%)      | 12 (27.9)      |
| Thrombolysis, n (%)                                  | 21 (48.8)      |
| **Ejection fraction**                                |                |
| <50, n (%)                                           | 20 (46.5)      |
| ≥50, n (%)                                           | 23 (53.5)      |

Figure 1. Study inclusion and exclusion criteria

Table 2. Lesion characteristics

| Lesion characteristics                                                                 |
|---------------------------------------------------------------------------------------|
| Plaque rupture                                                                         |
| Plaque erosion                                                                         |
| No specific lesion character                                                          |
| Intimal dissection without any plaque                                                 |
| Fibroatheromatous                                                                      |
| Fibrous                                                                               |

Figures 2 and 3 show OCT images for
fibroatheromatous plaque and red thrombus, respectively, in individual patients.

### Plaque and thrombus characteristics comparison

Plaque rupture was more commonly associated with fibroatheromatous plaques, whereas plaque erosion was more commonly associated with fibrous plaque (p=0.010). Plaque rupture and erosion were both more commonly seen in patients with STEMI, although not statistically significant. Plaque rupture was also more commonly associated with thin-cap fibroatheroma, although not statistically significant. The plaque and thrombus character comparison is shown in Table 3.

### Lesion characteristics comparison

The mean minimal lumen area (MLA) was higher in patients with plaque erosion than in those with plaque rupture (2.64±1.78 vs. 2.96±1.43 mm²), and the mean fibrous cap thickness was higher in patients with plaque erosion than in those with plaque rupture (126.67±48.22 vs. 105.71±48.02 µm). Lesion length was higher in patients with plaque rupture compared with those with plaque erosion (20.86±7.91 vs. 18.56±7.59 mm). However, none of these differences were found to be statistically significant. The comparison of lesion characteristics is shown in Table 4.

### Lipid profile

Mean cholesterol was 172.84±49.66 mg/dL. Mean low-density lipoprotein cholesterol (LDL-C) was 83.21±40.85 mg/dL, and high-density lipoprotein was 41.65±9.86 mg/dL. The lipid parameters are detailed in Table 5.

### Discussion

In this study, we aimed to shed light on culprit lesion characteristics in very young patients presenting with ACS by OCT. Of

| Characteristics | Patients (n=43) |
|-----------------|----------------|
| **Number of diseased vessels** | |
| Single-vessel disease, n (%) | 36 (83.7) |
| Double-vessel disease, n (%) | 6 (14.0) |
| Triple-vessel disease, n (%) | 1 (2.3) |
| **Culprit artery on coronary angiography** | |
| Left anterior descending artery, n (%) | 35 (81.4) |
| Right coronary artery, n (%) | 6 (14.0) |
| Left circumflex artery, n (%) | 2 (4.7) |
| **Plaque character** | |
| Plaque rupture, n (%) | 22 (51.2) |
| Plaque erosion, n (%) | 16 (37.2) |
| Others, n (%) | 5 (11.6) |
| **Plaque character** | |
| Nil, n (%) | 2 (4.7) |
| Fibroatheroma, n (%) | 34 (79.1) |
| Fibrous, n (%) | 7 (16.3) |
| **Management** | |
| Medical, n (%) | 8 (18.6) |
| Percutaneous coronary intervention, n (%) | 34 (79.1) |
| Thrombosuction, n (%) | 1 (2.3) |
| **Thrombus** | |
| Nil, n (%) | 11 (25.6) |
| Red, n (%) | 12 (27.9) |
| Red and white, n (%) | 11 (25.6) |
| White, n (%) | 9 (20.9) |

| Table 2. Lesion characteristics of study population |
|-----------------|----------------|
| **Characteristics** | **Patients (n=43)** |
| Number of diseased vessels | |
| Single-vessel disease, n (%) | 36 (83.7) |
| Double-vessel disease, n (%) | 6 (14.0) |
| Triple-vessel disease, n (%) | 1 (2.3) |
| Culprit artery on coronary angiography | |
| Left anterior descending artery, n (%) | 35 (81.4) |
| Right coronary artery, n (%) | 6 (14.0) |
| Left circumflex artery, n (%) | 2 (4.7) |
| Plaque character | |
| Plaque rupture, n (%) | 22 (51.2) |
| Plaque erosion, n (%) | 16 (37.2) |
| Others, n (%) | 5 (11.6) |
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| Red and white, n (%) | 11 (25.6) |
| White, n (%) | 9 (20.9) |

| Table 3. Plaque and thrombus characteristics comparison |
|-----------------|----------------|
| **Characteristics** | **OCT findings** | **Plaque rupture (n=22)** | **Plaque erosion (n=16)** | **Total (n=38)** | **P-value** |
| Plaque character | | 21 (95.5) | 10 (62.5) | 31 (81.8) | 0.010 |
| Fibroatheroma, n (%) | | 1 (4.5) | 6 (37.5) | 7 (18.4) | |
| Fibrous, n (%) | | 7 (31.8) | 1 (6.2) | 8 (21.1) | 0.056 |
| Thin-cap fibroatheroma, n (%) | | | | | |
| Thrombus | | 1 (4.5) | 5 (31.2) | 6 (15.8) | 0.050 |
| Nil, n (%) | | 8 (36.4) | 4 (25.0) | 12 (31.6) | |
| Red, n (%) | | 9 (40.9) | 2 (12.5) | 11 (28.9) | |
| Red and white, n (%) | | 4 (18.2) | 5 (31.2) | 9 (23.7) | |
| White, n (%) | | | | | |
| Clinical presentation | | 17 (77.3) | 12 (75.0) | 29 (76.3) | 0.871 |
| ST-segment elevation myocardial infarction, n (%) | | 5 (22.7) | 4 (25.0) | 9 (23.7) | |

OCT - optical coherence tomography
the 43 patients who underwent OCT imaging, 22 (51.2%) had plaque rupture, 16 (37.2%) had plaque erosion, and five (11.6%) had no specific lesion character.

Numerous autopsy series and imaging studies have been performed to identify the culprit lesion characteristics. Identification of plaque with intact caps (plaque erosion) as culprit lesions has garnered much interest. Many of these studies relied on OCT imaging owing to its superior spatial resolution (15 µm) compared with that of IVUS (100–200 µm) (13).

Evidence in literature suggests an uncommon occurrence of atherosclerotic plaque or high plaque burden in young patients with ACS. In this study, patients with ACS aged 35 years or less were included, and 41 (95.4%) have shown plaques as a cause for ACS. Earlier, Russo et al. (18) studied underlying mechanisms of ACS in Caucasian and Asian populations. The study concluded that Asian and Caucasian patients with ACS showed similar underlying mechanisms, except for a higher risk of calcified plaque in the Caucasian population with NSTEMI-ACS.

Table 6 represents plaque characteristics such as plaque rupture, plaque erosion, and calcified nodule observed in this study with that of other studies assessing culprit lesion morphologies causing STEMI using OCT.

Our study included predominantly men (97.7%) and did not provide ample samples for women for sex stratification of patients with ACS. Although earlier studies had witnessed significantly higher prevalence of plaque erosion in women of younger age, this finding was not confirmed in the OCTAVIA study (19), which was designed to assess sex differences in the pathophysiology of STEMI. Similarly, Fang et al. (20) have studied culprit lesion morphology in young patients with STEMI and older patients. Culprit lesions in younger patients with STEMI had more plaque erosion (32.0% vs. 21.1%, p<0.001) and larger minimal lumen area (2.3±1.7 mm² vs. 1.9±1.1 mm², p<0.001) than in those in older patients. Similar to these findings, the study by Jia et al. (7) has observed more plaque erosion in younger patients. However, prevalence of these lesions was not greater in women than men. The justification provided for this discrepancy was selection bias as patients of varying clinical presenta-
tion, age, history, and thrombotic state were included in the various studies.

Other plaque characteristics observed in our study correlate with the previous studies. Plaque erosion had more fibrous plaque and less thin-cap fibroatheroma (21-23). Plaque erosion had a thicker fibrous cap (7, 21, 23). However, plaque rupture had greater lesion length (7, 23).

The assessment of culprit lesion morphology in young patients might throw a light on the etiopathogenesis of ACS in this age group compared with that in older patients. Knowledge of the etiopathogenesis of ACS may help in its prevention. Further studies are required to identify if this subset benefits from conservative management rather than stent implantation.

**Conclusion**

This study exclusively included patients with ACS below 35 years of age, whose culprit lesion characters were studied. Although plaque rupture and plaque erosion occurred at the same rate as seen in patients of all age groups, calcified nodule as a culprit lesion was not found in very young patients. This study proves that plaque erosion occurs in a significant number of very young patients presenting with ACS. Further studies are required to identify if this subset benefits from conservative management rather than stent implantation.

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![Figure 3](image_url)

**Figure 3.** Optical coherence tomography showing a red thrombus (arrow) in a 36-year-old patient with anterior wall myocardial infarction. Angiography showed 70% lesion in the proximal left anterior descending coronary artery.

**Table 6.** Underlying culprits for acute coronary syndromes on optical coherence tomography

| Study            | Lesions | Plaque rupture | Plaque erosion | Calcified nodule |
|------------------|---------|----------------|----------------|------------------|
| Wang et al. (22) | 64      | 57.8%          | 39.0%          | 3.1%             |
| Kajander et al. (24) | 70 | 46.8%          | 44.3%          | 7.1%             |
| Saia et al. (21) | 97      | 64.9%          | 33.0%          | -                |
| Higuma et al. (23) | 112 | 64.3%          | 26.8%          | 8.0%             |
| Jia et al. (7)   | 126     | 43.7%          | 31.0%          | 7.9%             |
| Hu et al. (25)   | 141     | 56.0%          | 44.0%          | -                |
| This study       | 43      | 51.2%          | 37.2%          | -                |

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