Ventricular Fibrillation During Optical Coherence Tomography/Optical Frequency Domain Imaging — A Large Single-Center Experience —

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Background: The risks of ventricular fibrillation (Vfib) associated with frequency-domain optical coherence tomography (OCT)/optical frequency domain imaging (OFDI) remain undetermined.

Methods and Results: We retrospectively studied the occurrence of Vfib during OCT/OFDI for unselected indications. The frequency of Vfib and patient and procedural characteristics were investigated. A total of 4,467 OCT/OFDI pullback examinations were performed in 1,754 patients (median of 2.0 [2.0−3.0] pullbacks for 1.0 [1.0−1.3] vessels). OCT/OFDI was performed during PCI in 899 patients (51.3%). The contrast injection volume per pullback was 14.4 (11.7−17.2) mL with a flow rate of 3.4 (3.2−3.5) mL/s. Vfib occurred in 31 pullbacks (0.69%) in 30 patients (1.7%). No cases of Vfib occurred when using low-molecular-weight dextran. On multivariate analysis, contrast volume was the only independent factor for predicting Vfib (odds ratio, 1.080; 95% confidence interval, 1.008−1.158, P=0.029). The best cutoff value of contrast volume for predicting Vfib was 19.2 mL (area under the curve, 0.713, P<0.001; diagnostic accuracy, 87.1%).

Conclusions: The present large, single-center registry study indicated that Vfib during OCT/OFDI was rare for unselected indications. Contrast injection volume used to displace blood should be limited to avoid Vfib.

Key Words: Contrast; Intravascular imaging; Optical coherence tomography; Optical frequency domain imaging; Ventricular fibrillation

Intracoronary optical coherence tomography (OCT) using near infrared light has been increasingly used for clinical indications, including optimization of stent placement, coronary lesion assessment, and the evaluation of stent healing and stent failure.\textsuperscript{1-5} Previously, 1st-generation time-domain OCT required proximal balloon occlusion to displace blood in combination with distal solution injection. Current widely used 2nd-generation frequency-domain OCT/optical frequency domain imaging (OFDI) overcomes this limitation by providing simplified non-occlusive image acquisition with higher frame rate, higher resolution, and fast pullback speed than before. Previously reported complications associated with time-domain OCT and frequency-domain OCT include ventricular fibrillation (Vfib), ST-segment elevation, bradycardia, coronary spasm, dissection, stent deformation, chest pain, and air embolism.\textsuperscript{1,4-10} A previous study evaluated the safety of time-domain OCT performed on 468 patients and reported that Vfib occurred in 1.1% of cases.\textsuperscript{6} Vfib is potentially a lethal and significant complication during OCT/OFDI, but its frequency of occurrence during frequency-domain OCT/OFDI remains unknown. The ability of current OCT/OFDI systems to provide long segment imaging by fast pullback may, in some cases, increase contrast injection time and contrast volume to displace blood, resulting in increased occurrence of Vfib. The purpose of this large single-center
registry study was to assess, for the first time, the frequency of occurrence of Vfib during OCT/OFDI examinations and to evaluate the predictive factors for Vfib for unselected and heterogeneous indications in real-world practice.

Methods

Patient Population

This study was conducted in compliance with the institutional ethic committee guidelines and received its approval. The present study also complied with the Declaration of Helsinki for investigation in human beings, and all patients provided written informed consent for future data utilization before coronary angiography and OCT/OFDI examinations. Consecutive patients with coronary artery disease (CAD) who had OCT/OFDI examination performed between March 2016 and March 2019 for unselected indications were included (Figure 1). The present study period was chosen because, after March 1st, 2016, 12-lead ECG and pressure recordings throughout the catheterization procedure were stored and accessible for reference at our institution. Our institutional OCT/OFDI registry included all OCT/OFDI examinations for either diagnostic or therapeutic catheterization. OCT/OFDI procedures for the culprit lesions of acute coronary syndrome (ACS) were not excluded. This registry also included cases for clinical research of stent healing and follow-up OCT/OFDI examinations after percutaneous coronary intervention (PCI) according to each study protocol. Lesions in extremely tortuous vessels or with heavy calcification were excluded because of expected difficulty in advancing the OCT/OFDI catheters. We did not exclude patients with angiographically significant left main disease or with stent implantation in the left main trunk. Final decision to perform OCT/OFDI examinations was at the operator’s discretion. Cases of the imaging catheter failing to cross were excluded from the analysis.

Cardiac Catheterization and OCT/OFDI Image Acquisition

Each patient initially underwent standard selective coronary angiography. Coronary angiograms were analyzed quantitatively using a QAngio XA system (Medis Medical Imaging Systems, Leiden, The Netherlands) to measure minimum lumen diameter, reference vessel diameter, percent diameter stenosis, and length of the target lesion, if indicated. All patients received a bolus injection of heparin (5,000 IU) before the procedure, and an additional bolus injection (2,000 IU) was administered every hour as needed. An intracoronary bolus injection of nitroglycerin (0.2 mg) was administered at the start of the procedure and repeated every 30 min. OCT/OFDI was performed via radial access using 5-Fr, 6-Fr, or 7-Fr guiding catheter according to the institutional standard protocol at the target or non-target lesions as a part of diagnostic catheterization for evaluating lesion morphology or stent healing and/or PCI for assessing lesion morphology and stent optimization. OCT/OFDI images were acquired using frequency-domain OCT systems: Abbott OCT (ILUMIEN OPTIS™, Abbott Vascular,
expert interventionalists, all of whom had at least 300 cases of OCT/OFDI examinations as an operator at the time of March 2016.

**Documentation of Vfib**

Vfib occurrence was individually adjudicated by 2 independent cardiologists by reviewing ECG recordings during OCT/OFDI examinations identified by markings of each OCT/OFDI procedure. After adjudication of Vfib, the type of flushing agent, injection time length, injection flow rate, and injection volume of flushing agent were documented. The Vfib induction trigger such as R on T was also assessed and the length of time after the end of injection of flushing agent was measured. In all cases of Vfib, the time required

<table>
<thead>
<tr>
<th>Table 1. Patients’ Characteristics</th>
<th>Total (n=1,754)</th>
<th>Vfib (n=30)</th>
<th>No Vfib (n=1,724)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td>0.637</td>
</tr>
<tr>
<td>Male</td>
<td>1,443 (82.2)</td>
<td>26 (86.7)</td>
<td>1,417 (82.2)</td>
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<tr>
<td>Female</td>
<td>311 (17.8)</td>
<td>4 (13.3)</td>
<td>307 (17.8)</td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>69 (62–75)</td>
<td>70 (61–73)</td>
<td>69 (62–75)</td>
<td>0.980</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.6 (22.2–26.7)</td>
<td>25.0 (22.6–26.8)</td>
<td>24.5 (22.1–26.6)</td>
<td>0.245</td>
</tr>
<tr>
<td>Indication of OCT/OFDI</td>
<td></td>
<td></td>
<td></td>
<td>0.466</td>
</tr>
<tr>
<td>Diagnostic catheterization</td>
<td>855 (48.7)</td>
<td>14 (46.7)</td>
<td>841 (48.8)</td>
<td></td>
</tr>
<tr>
<td>Elective PCI</td>
<td>538 (30.7)</td>
<td>12 (40.0)</td>
<td>526 (30.5)</td>
<td></td>
</tr>
<tr>
<td>Primary/emergency PCI</td>
<td>361 (20.6)</td>
<td>4 (13.3)</td>
<td>357 (20.7)</td>
<td></td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
<td></td>
<td>0.716</td>
</tr>
<tr>
<td>Stable CAD</td>
<td>1,358 (77.4)</td>
<td>26 (86.7)</td>
<td>1,332 (77.3)</td>
<td></td>
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<tr>
<td>NSTE-ACS</td>
<td>223 (12.7)</td>
<td>2 (6.7)</td>
<td>221 (12.8)</td>
<td></td>
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<tr>
<td>STEMI</td>
<td>160 (9.1)</td>
<td>2 (6.7)</td>
<td>158 (9.2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>13 (0.7)</td>
<td>0 (0.0)</td>
<td>13 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Prior MI</td>
<td>831 (47.4)</td>
<td>13 (43.3)</td>
<td>818 (47.4)</td>
<td>0.715</td>
</tr>
<tr>
<td>Prior PCI</td>
<td>1,241 (70.8)</td>
<td>21 (70.0)</td>
<td>1,220 (70.8)</td>
<td>1.000</td>
</tr>
<tr>
<td>Prior CABG</td>
<td>37 (2.1)</td>
<td>1 (3.3)</td>
<td>36 (2.1)</td>
<td>0.475</td>
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<tr>
<td>Hypertension</td>
<td>1,192 (68.0)</td>
<td>21 (70.0)</td>
<td>1,171 (67.9)</td>
<td>1.000</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>1,034 (59.0)</td>
<td>21 (70.0)</td>
<td>1,013 (58.8)</td>
<td>0.263</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>765 (43.6)</td>
<td>10 (33.3)</td>
<td>755 (43.8)</td>
<td>0.272</td>
</tr>
<tr>
<td>Current smoking</td>
<td>582 (33.2)</td>
<td>9 (30.0)</td>
<td>573 (33.2)</td>
<td>0.846</td>
</tr>
<tr>
<td>eGFR, mL/min/1.73 m²</td>
<td>65.1 (52.8–77.4)</td>
<td>71.2 (61.8–75.3)</td>
<td>64.9 (52.7–77.4)</td>
<td>0.177</td>
</tr>
<tr>
<td>HbA1C, %</td>
<td>6.1 (5.7–6.8)</td>
<td>6.1 (5.7–6.6)</td>
<td>6.1 (5.7–6.8)</td>
<td>0.500</td>
</tr>
<tr>
<td>LDL-C, mg/dL</td>
<td>88 (73–108)</td>
<td>83 (69–105)</td>
<td>88 (73–109)</td>
<td>0.465</td>
</tr>
<tr>
<td>HDL-C, mg/dL</td>
<td>46 (39–55)</td>
<td>48 (38–54)</td>
<td>46 (39–55)</td>
<td>0.889</td>
</tr>
<tr>
<td>TG, mg/dL</td>
<td>122 (85–179)</td>
<td>124 (87–166)</td>
<td>122 (85–179)</td>
<td>0.938</td>
</tr>
<tr>
<td>WBC count, /μL</td>
<td>6,300 (5,170–7,790)</td>
<td>6,700 (5,380–7,595)</td>
<td>6,300 (5,170–7,790)</td>
<td>0.664</td>
</tr>
<tr>
<td>Hemoglobin, g/dL</td>
<td>13.1 (12.1–14.3)</td>
<td>13.7 (12.3–14.2)</td>
<td>13.1 (12.0–14.4)</td>
<td>0.483</td>
</tr>
<tr>
<td>CRP, mg/dL</td>
<td>0.07 (0.03–0.20)</td>
<td>0.06 (0.03–0.15)</td>
<td>0.07 (0.03–0.21)</td>
<td>0.224</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>61 (52–67)</td>
<td>64 (59–69)</td>
<td>61 (53–67)</td>
<td>0.089</td>
</tr>
<tr>
<td>ECG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>60 (3.4)</td>
<td>2 (6.7)</td>
<td>58 (3.4)</td>
<td>0.274</td>
</tr>
<tr>
<td>Abnormal Q wave</td>
<td>357 (20.4)</td>
<td>9 (30.0)</td>
<td>348 (20.4)</td>
<td>0.186</td>
</tr>
<tr>
<td>QT prolongation</td>
<td>364 (20.8)</td>
<td>5 (16.7)</td>
<td>359 (20.8)</td>
<td>0.820</td>
</tr>
<tr>
<td>OCT/OFDI procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of pullbacks per patient</td>
<td>2.0 (2.0–3.0)</td>
<td>2.5 (2.0–3.0)</td>
<td>2.0 (2.0–3.0)</td>
<td>0.882</td>
</tr>
<tr>
<td>No. of interrogated vessels per patient</td>
<td>1.0 (1.0–1.3)</td>
<td>1.0 (1.0–2.0)</td>
<td>1.0 (1.0–1.0)</td>
<td>0.601</td>
</tr>
</tbody>
</table>

Data are presented as number (%) or median (interquartile range). CAD, coronary artery disease; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate; HbA1C, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; NSTE-ACS, non-ST-segment-elevation acute coronary syndrome; OCT, optical coherence tomography; OFDI, optical frequency domain imaging; PCI, percutaneous coronary intervention; STEMI, ST-segment-elevation myocardial infarction; TG, triglyceride; Vfib, ventricular fibrillation; WBC, white blood cells.
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**Results**

**Baseline Patient Characteristics and Procedural Findings**

Between March 2016 and March 2019, a total number of 4,467 OCT/OFDI pullbacks in 1,754 patients were performed and eligible for the analysis. Table 1 shows the baseline clinical, angiographic, and procedural characteristics of the patients. OCT/OFDI was performed in 855 diagnostic catheterizations in 855 patients (48.7%) with 1,641 pullbacks (36.7%) and in 899 PCI in 899 patients (51.3%) with 2,826 pullbacks (63.3%) (Figure 1). PCI included 361 procedures in ACS (ST-segment-elevation myocardial infarction, 160 patients [17.8%] with 408 pullbacks [14.4%]; non-ST-segment-elevation ACS, 201 patients [22.4%] with 641 pullbacks [22.7%]) and 538 procedures in stable CAD (538 patients [59.8%] with 1,777 pullbacks [62.9%]). The median number of pullbacks per patient was 2.0 [2.0–3.0] for 1.0 [1.0–1.3] vessels. The left anterior descending was the most frequently interrogated vessel linear combinations among covariates to avoid overfitting.
A total of 31 cases of Vfib occurred in 30 patients (per patient, 30/1,754 [1.7%]; per pullback, 31/4,467 [0.69%]). The incidence of Vfib per patient was 1.6% (14/855) during diagnostic catheterization, 2.2% (12/538) during elective PCI, and 1.1% (4/361) during primary or emergency PCI (P=0.466). There was no discordant adjudication of Vfib between the 2 cardiologists.

Table 2. Pullback-Based OCT/OFDI Procedural Findings

<table>
<thead>
<tr>
<th>Indication of OCT/OFDI</th>
<th>Total (n=4,467)</th>
<th>Vfib (n=31)</th>
<th>No Vfib (n=4,436)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic catheterization</td>
<td>1,641 (36.7)</td>
<td>15 (48.4)</td>
<td>1,626 (36.7)</td>
<td>0.286</td>
</tr>
<tr>
<td>Elective PCI</td>
<td>1,777 (39.8)</td>
<td>12 (38.7)</td>
<td>1,765 (39.8)</td>
<td></td>
</tr>
<tr>
<td>Primary/emergency PCI</td>
<td>1,049 (23.5)</td>
<td>4 (12.9)</td>
<td>1,045 (23.6)</td>
<td></td>
</tr>
</tbody>
</table>

| Diagnosis                     |            |             |                   |         |
| Stable CAD                    | 3,360 (75.2) | 27 (87.1)   | 3,333 (75.1)      |         |
| NSTE-ACS                      | 684 (15.3)  | 2 (6.5)     | 682 (15.4)        | 0.426   |
| STEMI                         | 408 (9.1)   | 2 (6.5)     | 406 (9.2)         |         |
| Other                         | 15 (0.3)    | 0 (0.0)     | 15 (0.3)          |         |

| Guide catheter                |            |             |                   |         |
| 5-Fr                          | 1,583 (35.4) | 14 (45.2)   | 1,569 (35.4)      |         |
| 6-Fr                          | 2,407 (53.9) | 14 (45.2)   | 2,393 (53.9)      |         |
| 7-Fr                          | 477 (10.7)  | 3 (9.6)     | 474 (10.7)        |         |

| System                        | 4,194 (93.9)| 24 (77.4)   | 4,170 (94.0)      | 0.002   |
| OFDI                          | 273 (6.1)   | 7 (22.6)    | 266 (6.0)         |         |

| Interrogated vessel           |            |             |                   | 0.072   |
| LAD                           | 2,426 (54.3)| 17 (54.8)   | 2,409 (54.3)      |         |
| LCX                           | 687 (15.4)  | 3 (9.7)     | 684 (15.4)        |         |
| RCA                           | 1,334 (29.9)| 11 (35.5)   | 1,323 (29.8)      |         |
| Graft                         | 20 (0.4)    | 0 (0.0)     | 20 (0.5)          |         |

| Flushing agent                |            |             |                   |         |
| Contrast                      | 3,984 (89.2)| 31 (100.0)  | 3,953 (89.2)      |         |
| LMWD                          | 481 (10.8)  | 0 (0.0)     | 481 (10.8)        |         |

| Injection parameters          |            |             |                   |         |
| Flow rate, mL/s              | 3.4 (3.2–3.6)| 3.4 (3.2–3.4)| 3.4 (3.2–3.6)      | 0.148   |
| Injection volume, mL         | 14.9 (12.0–18.1)| 19.3 (14.8–22.9)| 14.9 (12.0–18.1) | 0.002   |
| Injection time length, s     | 5.41 (4.62–6.15)| 6.31 (4.19–7.39)| 5.40 (4.62–6.13) | 0.064   |

| Contrast subgroup             |            |             |                   |         |
| Flow rate, mL/s              | 3.4 (3.2–3.5)| 3.4 (3.2–3.4)| 3.4 (3.2–3.5)      | 0.355   |
| Injection volume, mL         | 14.4 (11.7–17.2)| 19.3 (14.8–22.9)| 14.4 (11.7–17.2) | 0.001   |
| Injection time length, s     | 5.32 (4.77–5.97)| 6.31 (4.19–7.39)| 5.31 (4.77–5.97) | 0.031   |

| LMWD subgroup                 |            |             |                   |         |
| Flow rate, mL/s              | 4.0 (3.8–4.2)| –           | 4.0 (3.8–4.2)      |         |
| Injection volume, mL         | 22.0 (19.0–25.9)| –           | 22.0 (19.0–25.9)   |         |
| Injection time length, s     | 6.58 (6.00–7.33)| –           | 6.58 (6.00–7.33)   |         |

Data are presented as number (%) or median (interquartile range). LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; LMWD, low-molecular-weight dextran; RCA, right coronary artery. Other abbreviations are in Table 1.

(54.3%, 2,426 pullbacks). The bypass graft was also interrogated in a subset of patients (6 patients with 20 pullbacks).

OCT/OFDI examinations using LMWD were performed in 123 patients (7.0%) (481 pullbacks [10.8%]) with renal dysfunction (mean estimated glomerular filtration rate [eGFR], 43.2 mL/min/1.73 m²). LMWD was more frequently used in patients with lower ejection fraction (EF <50%) than in patients with higher EF (≥50%) (15.2% vs. 10.0%, P=0.001). Most procedures were done by OCT system (93.9%, 4,194/4,467 pullbacks). The median contrast injection volume for 1 pullback was 14.4 (11.7–17.2) mL with an injection flow rate of 3.4 (3.2–3.5) mL/s and injection time length of 5.32 (4.77–5.97) s. The median LMWD injection volume for 1 pullback was 20.0 (17.6–23.9) mL with an injection flow rate of 4.0 (3.8–4.2) mL/s and injection time length of 6.58 (6.00–7.33) s.

Occurrence of Vfib

A total of 31 cases of Vfib occurred in 30 patients (per patient, 30/1,754 [1.7%]; per pullback, 31/4,467 [0.69%]). The incidence of Vfib per patient was 1.6% (14/855) during diagnostic catheterization, 2.2% (12/538) during elective PCI, and 1.1% (4/361) during primary or emergency PCI (P=0.466). There was no discordant adjudication of Vfib between the 2 cardiologists. Figure 2 shows 2 representative cases of Vfib and Table 2 shows the procedural characteristics of 2 groups divided according to the occurrence of Vfib. Injection volume of flushing agent per pullback in cases of Vfib was significantly greater compared with those without (19.3 [14.8–22.9] vs. 14.9 [12.0–18.1] mL, P=0.002). Injection flow rate was not different between groups. Of the 31 Vfib cases, 17 (54.8%) occurred with the first OCT/OFDI pullback, and in 9 cases (29.0%) with the second pullback; 5 cases (16.1%) occurred with 3rd or subsequent
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Table 3 shows the results of univariable and multivariable analyses of the predictors of Vfib. Injection volume was the only independent factor for predicting Vfib (odds ratio, 1.080; 95% confidence interval, 1.008–1.158; P=0.029). Receiver-operating characteristic curve analysis showed that the best cutoff value of contrast volume for predicting Vfib was 19.2 mL (area under the curve, 0.713, P<0.001; sensitivity, 51.7%; specificity, 87.4%; diagnostic accuracy, 87.1%, respectively) (Figure 3). No cases of Vfib occurred with contrast volume <9.5 mL.

Discussion

To the best of our knowledge, this is the first study using a large single-center registry demonstrating that the frequency of occurrence of Vfib during contemporary frequency-domain OCT/OFDI was very low in unselected real-world practice. We also identified that the contrast volume to displace blood for OCT/OFDI examinations was an independent predictor of Vfib and that the best cutoff value of contrast volume to predict Vfib was 19.2 mL. Furthermore, our results indicated that stenosis severity, OCT/OFDI indication, and vessel interrogated were not predictive for Vfib.

Of interest, LMWD was protective for Vfib, notwithstanding greater injection volume of LMWD compared with contrast injection. The viscosity of LMWD is 4.99 mPa·s, which is significantly lower than that of iopamidol (9.1 mPa·s [37°C]) but high enough to allow blood displacement during OCT/OFDI image acquisition. The

pullbacks (P=NS). In cases where the OFDI system was used, Vfib occurred in 7 of 273 pullbacks (2.6% vs. 0.57% [24/4,170] with OCT system, P=0.002). The use of OFDI was associated with increased contrast volume (OFDI vs. OCT; 21.1 [17.6–24.4] mL vs. 14.1 [11.6–16.7] mL, P<0.001).

Distribution of interrogated vessel, OCT/OFDI indication (stable CAD, elective PCI, primary/emergency PCI), and baseline ECGs were not significantly different between groups. Stenosis severity of the interrogated vessel was not significantly different between groups (Vfib vs. non-Vfib; 24.8 [11.9–38.5] % vs. 23.9 [10.6–41.0] %, P=0.23). Of note, no cases of Vfib occurred when LMWD (123 patients [7.0%] with 481 pullbacks [10.8%]) was used to displace blood, although injection volume of LMWD per pullback was significantly greater than with contrast injection (22.0 [19.0–25.9] mL vs. 14.4 [11.7–17.2] mL, P<0.001). The median length of time before the occurrence of Vfib after the end of contrast volume injection was 2.97 (2.07–5.38) s. In 1 case of Vfib the patient showed complete atrioventricular block after the end of contrast injection and before Vfib occurrence (Figure 2). The Vfib trigger was R on T in all cases. In 30 patients exhibiting Vfib, 10 underwent subsequent OCT/OFDI examinations after sinus rhythm restoration. Among these patients, 1 further case of Vfib occurred. No apparent case of pressure dumping was documented at the start of contrast injection suggestive of deep engagement of the guiding catheter in the present cohort. In 30 of 31 Vfib episodes, sinus restoration was promptly obtained by 1 external defibrillation shock. In the remaining case, 4 external defibrillation shocks were required to restore sinus rhythm with advanced cardiac life support procedure. No sustained complications, permanent harm, or prolongation of hospital stay because of Vfib were observed in patients with Vfib.

Predictors of Vfib

Table 3 shows the results of univariable and multivariable analyses of the predictors of Vfib. Injection volume was the only independent factor for predicting Vfib (odds ratio, 1.080; 95% confidence interval, 1.008–1.158; P=0.029). Receiver-operating characteristic curve analysis showed that the best cutoff value of contrast volume for predicting Vfib was 19.2 mL (area under the curve, 0.713, P<0.001; sensitivity, 51.7%; specificity, 87.4%; diagnostic accuracy, 87.1%, respectively) (Figure 3). No cases of Vfib occurred with contrast volume <9.5 mL.

Discussion

To the best of our knowledge, this is the first study using a large single-center registry demonstrating that the frequency of occurrence of Vfib during contemporary frequency-domain OCT/OFDI was very low in unselected real-world practice. We also identified that the contrast volume to displace blood for OCT/OFDI examinations was an independent predictor of Vfib and that the best cutoff value of contrast volume to predict Vfib was 19.2 mL. Furthermore, our results indicated that stenosis severity, OCT/OFDI indication, and vessel interrogated were not predictive for Vfib.

Of interest, LMWD was protective for Vfib, notwithstanding greater injection volume of LMWD compared with contrast injection. The viscosity of LMWD is 4.99 mPa·s, which is significantly lower than that of iopamidol (9.1 mPa·s [37°C]) but high enough to allow blood displacement during OCT/OFDI image acquisition. The
osmolarity of LMWD, an isotonic solution, is 285 mOsm/L, which is significantly lower than that of the low-osmolar contrast agent, iopamidol (897 mOsm/L on average). In contrast with non-ionic contrast agents, LMWD contains potassium (4 mEq/L) and calcium (3 mEq/L), which could prevent fatal ventricular arrhythmias during coronary injection, although definitive mechanisms remain to be determined. LMWD was more frequently used in patients with lower EF, probably because of the interrelationship between EF and renal function. This trend might have resulted in the association between better LVEF and Vfib occurrence as shown in Table 3. However, this result should be interpreted with caution, as the number of Vfib events was small and the trend in favor of LMWD to avoid Vfib did not reach statistical significance.

An intriguing issue was the association of Vfib and imaging system used. Vfib occurred more frequently when using OFDI compared with OCT. This is likely attributable to the specification of OFDI, which provides longer interrogation length, resulting in the inevitable link with increased contrast volume. OFDI has a capability of, at most, 150-mm pullback length by various pullback speed settings. When using 20 mm/s or 25 mm/s pullback speed for full-length scan, contrast volume can easily reach up to 20 mL or more. This characteristic has to be considered when using OFDI.

Prati et al previously reported time-domain OCT imaging with a non-occlusive technique and demonstrated feasibility and low complication risk.14 Barlis et al15 then reported a large multicenter registry of 468 patients in whom they performed time-domain OCT using an occlusion balloon in 256 patients (54.7%) and a non-occlusive flushing technique in the remaining 212 (45.3%) patients. In their study, Vfib occurred in 5 cases (1.1%) and they speculated that deep engagement of the guiding catheter during simultaneous contrast injection was linked to Vfib in 2 OCT cases (0.94%) of the non-occlusive technique. However, there are few data on the safety of frequency-domain OCT in a large study population. Previous data show that the incidence of Vfib during coronary intervention is approximately 1.0–2.0%12 and 0.6% for diagnostic catheterization.13 A recent study also showed that OCT was safe and almost all adverse events were self-limiting.10 They did not find any patient characteristics or procedural factors that may predict Vfib in the light of a very low event rate from 1,142 procedures. In contrast, our results clearly indicated that contrast volume was a significant predictor of Vfib for unselected indications in a very large registry of a high-volume center. When contrast volume was less than 9.5 mL, no cases of Vfib were observed. The OCT/OFDI catheter itself may contribute to flow obstruction and subsequent ischemia, which might induce susceptibility to Vfib. The OCT/OFDI examination requires displacement of blood to obtain a clear view for intracoronary imaging, which may introduce an inevitable bias to increasing the contrast volume to displace blood after a test injection at the operator’s discretion. By injecting the contrast for a certain length of time, physiological coronary flow is interrupted, and subsequent ischemia might be linked with Vfib. In addition, other mechanisms have been suggested, including osmolarity, viscosity and other compositional aspects of contrast agents, electrolyte imbalance, intracoronary thrombus and air embolism.14–16

The most important feature of OCT/OFDI is its ability to provide high-resolution images of coronary stents and coronary lesions.1 OCT/OFDI can accurately evaluate stent strut apposition and intimal healing patterns such as neoatherosclerosis, all of which have been reported to be related to stent failure. OCT/OFDI can classify the culprit lesion morphology of ACS from the pathological standpoint, including thin-cap fibroatheroma, plaque rupture, plaque erosion, and calcified nodules, which potentially improves the management and prognosis of patients with CAD. With faster pullback speeds and simplified procedures as well as further sophistication of proprietary software-assisted interpretation, OCT/OFDI may become more widely used. For primary and secondary prevention, multivessel OCT/OFDI interrogations will also increase the number of long pullback procedures for an entire coronary assessment with subsequent greater contrast volumes required. OCT/OFDI needs to be done without increased risk associated with actual imaging procedure. Our results demonstrated that Vfib associated with OCT/OFDI is a rare complication, but non-self-limiting. The present study demonstrated the factors to be taken into account to avoid Vfib when performing OCT/OFDI: limiting the contrast volume per pullback and optional use of LMWD for displacing blood particularly in cases that will require long pullbacks.

Study Limitations
Our results should be interpreted while considering several important limitations. First, the present study was a retrospective analysis over 3 years of a single-center large OCT/OFDI database for consecutive unselected and heterogeneous indications in real-world practice. The final decision to perform OCT/OFDI was at the operator’s discretion, possibly causing inconsistency and inevitable bias. Vfib adjudication and procedure evaluation of a large volume registry was done by using medical charts and 12-lead...
ECG recordings during whole catheterization procedures, resulting in a reduction in the possibility of wrong identification. Second, iopamidol is the contrast agent that has been preferentially used in our catheterization laboratory and also used for displacing blood during OCT/OFDI examinations. Osmolarity and/or viscosity, as well as the concentrations of other components such as sodium and chloride, may affect susceptibility to Vfib when using other contrast agents. Third, the influence of multivessel disease on the occurrence of Vfib was not evaluated. In our study cohort, some patients with ACS underwent pre- and post-PCI OCT/OFDI examinations of the culprit lesion, and some underwent OCT/OFDI examination for the non-culprit lesion before or after culprit lesion assessment/treatment. The impact of multivessel disease or ischemic burden on Vfib occurrence is an important factor to be taken into consideration; however, it might be controversial to define the extent of ischemia in the present study population. Finally, we did not assess the relationship between the operator’s experience of imaging procedures and Vfib occurrence, because all of the invasive OCT/OFDI examinations were performed by highly experienced operators.

Conclusions

Vfib associated with OCT/OFDI examinations was rare for unselected and heterogeneous practical indications. Certain predictive factors, including reduction of contrast volume or the selection of flushing agent used, should be considered for safe OCT/OFDI application.

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None.

Disclosure

None declared.

References