The American Journal of Cardiology 236 (2025) 49−55

Contents lists available at ScienceDirect

The American Journal of Cardiology

journal homepage: www.elsevier.com/locate/ajc

Sex Differences in a Real-World Registry Examining Coronary Lithotripsy for Calcified Lesions

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ARTICLE INFO

Article History:
Received 26 September 2024
Revised 24 October 2024
Accepted 1 November 2024

Keywords:
coronary artery calcification (CAC)
intravascular lithotripsy (IVL)
sex-related differences

Intravascular lithotripsy (IVL) has been established as a safe and effective treatment for coronary artery calcification (CAC). This study aimed to evaluate sex-related differences in the treatment with IVL in a real-world, all-comers international registry. Patients who underwent IVL between May 2019 and February 2024 were enrolled from the BENELUX-IVL registry. Patients were divided into men and women groups. Efficacy end points included device success (delivery of the IVL balloon across the target lesion and administration of therapy without related complications), technical success (thrombolysis in myocardial infarction 3 flow and residual stenosis <30% by quantitative coronary analysis and/or fluoroscopically) and procedural success (composite of technical success with absence of in-hospital major adverse cardiovascular events (MACE: cardiac death, myocardial infarction or target vessel revascularization). Safety end points were IVL-related complications and MACE at 1-year follow-up. 454 patients (73 ± 9.0 years) were treated with IVL, comprising 342 men (75%) and 112 women (25%). More women presented with acute coronary syndrome (41% in men vs 54% in women; p = 0.014) and aorto-ostial lesions (17% in men vs 29% in women; p = 0.009), whereas the SYNTAX score (23.5 ± 14.2 in men vs 17.1 ± 1.0 in women; p <0.001) was higher in men. Rates of device success (97% vs 98%; p = 1.000), technical success (90% vs 91%; p = 0.821) procedural success (90% vs 88%; p = 0.749), IVL-related complications (1% vs 2%; p = 0.362) and 1-year MACE rates (12% vs 17%; p = 0.456) were comparable. In conclusion, despite differences in clinical presentation and lesion types, IVL seems to be safe and effective for both sexes across various clinical and anatomical scenarios.

Cardiovascular disease (CVD) is the leading cause of death in women but has historically been understudied compared with men, leading to fewer investigations and treatments within women.[1,2] More recently, research into sex-specific diagnoses and treatments for coronary artery disease (CAD) has increased.[3,4] Literature indicates that women typically develop atherosclerosis and coronary artery calcification (CAC) at a later age and exhibit less focal but more diffuse CAD, whereas men more often present with focal, although extensive, calcified disease.[5−7] However, CAC is increasingly encountered in all patients who underwent percutaneous coronary intervention (PCI).[8,9] CAC is associated with worse acute procedural success rates and increased in-hospital and long-term major adverse cardiovascular event (MACE) rates for both sexes.[8,10−13] Additionally, previous research has shown higher complication and/or MACE rates for women treated for CAC with rotational atherectomy (RA) and orbital atherectomy (OA).[14,15] Despite this, women are underrepresented in pivotal studies evaluating an alternative calcium modification technique: intravascular lithotripsy (IVL).[16] IVL has been established as a safe and effective treatment option for CAC, using shockwaves that cause fractures in calcium deposits in the vessel wall to facilitate the

Funding: This work was funded through a research grant from Shockwave Medical. Funders were not involved in any aspect of the study, including its design, collection, analysis, and interpretation of the data, or the writing of the manuscript.

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https://doi.org/10.1016/j.amjcard.2024.11.002
0002-9149/

use and expansion of stents.[16,17] Sex-specific patient-pooled analyses from the DISRUPT-CAD studies suggested comparable short-term and 1-year outcomes for both sexes.[18,19] However, these studies excluded higher-risk features like acute coronary syndrome (ACS). Therefore, the sex-related differences in the treatment of CAC with IVL in real-world contemporary practice remain unknown. This study aimed to address this gap by evaluating sex-related differences in the treatment of CAC with IVL in a real-world, international registry, focusing on differences in patient presentation, lesion characteristics, procedural approaches, and 1-year outcomes.

Methods

In this study, patients ≥18 years old who underwent PCI for CAC with IVL were prospectively enrolled from the multicenter international BENELUX-IVL registry. This registry included patients from 7 centers in 2 European countries between May 2019 and February 2024 and had the primary aim to evaluate the safety and efficacy of IVL in an unselected real-world patient cohort with data from an extended follow-up period. Subsequently, the patients were divided into men and women groups for comparison. IVL was performed in all cases using the Shockwave Intravascular Lithotripsy Coronary System (Shockwave Medical, Santa Clara, California). Decisions regarding technical aspects of IVL (timing, balloon size, number of pulses delivered, maximal inflation pressure), utilization of high-pressure predilatation and postdilatation, supplementary stent placement, and use of intracoronary imaging (ICI) for procedural optimization were left to the operator's discretion, with subsequent documentation of these decisions. Demographic, clinical, procedural, and follow-up data were collected from the hospital electronic records. Angiographic and ICI data were analyzed in a centralized core laboratory at the Leiden University Medical Center. Patients who were unable to provide informed consent were excluded from the study. The local ethical committee at each institution approved the retrospective analysis of clinically collected data.

Diagnostic angiograms were graded in the centralized corelab according to the SYNTAX score algorithm if all 3 vessels were visualized.[20] The presence of CAC was determined by the operator during the procedure both angiographically (fluoroscopic visibility of radiopacities in the vessel wall at the site of stenosis and/or noncompliant balloon underexpansion) and by ICI when available. Angiographic CAC was scored none/mild, moderate (when the radiopacities were only visible during cardiac motion before contrast injection), or severe (when the radiopacities were apparent without cardiac motion before contrast injection).[21,22] On intravascular ultrasound (IVUS) CAC was defined as a hyperechoic signal with acoustic shadowing, whereas on optical coherence tomography (OCT) CAC appeared as a signal-poor area with sharply delineated borders.[11,12,22,23]

Quantitative coronary analysis (QCA) and ICI were retrospectively analyzed offline to evaluate luminal gain after IVL. QCA was performed pre-IVL and post-IVL and stenting, using Medis Suite QCA (2D/3D) software (Medis Suite 4.0.24.4; Medis Medical Imaging System BV, Leiden, The Netherlands). Measurements included minimum lumen diameter (minimum LD), minimum lumen area (minimum LA), percentage diameter stenosis (DS), and percentage area stenosis (AS). Analysis of IVUS and OCT was performed using QCU-CMS 4.69 (Leiden University Medical Center). When available, ICI measurements were performed, including reference vessel diameter (RVD), reference vessel area (RVA), minimum LD, minimum LA, and minimum stent area (MSA). DS and AS were calculated using the formulas ([RVD−Minimum LD]/RVD) $\times$ 100 and ([RVA−Minimum LA]/RVA) $\times$ 100, respectively. Stent expansion was determined with the formula (MSA/RVA)*100, and the eccentricity index was computed by subtracting the minimum LD from the maximum LD at the Minimum LA and dividing it by the latter. Lastly, we documented the maximum calcification angle and thickness pre-IVL. The specified variables were compared between the first available recording pre-IVL and after IVL and stenting.

The primary end point of the study was the achievement of procedural success, a composite of residual stenosis <30% (assessed by QCA and/or fluoroscopically by the treating physician), final thrombolysis in myocardial infarction (TIMI) 3 coronary flow and absence of in-hospital major adverse cardiovascular events (MACE: cardiac death, non-fatal target vessel MI or clinically driven target lesion revascularization). Secondary end points included device success (defined as successful employment of the IVL catheter to the target lesion, and delivery of IVL pulses without direct angiographic complications), technical success (defined as the presence of TIMI 3 flow and residual stenosis <30% assessed by QCA or fluoroscopically) and the occurrence of MACE and all-cause mortality before discharge and at 1-year follow-up after IVL.

Continuous variables are presented as either the mean ± SD or median with an interquartile range (25th to 75th percentile), as appropriate. Differences between paired continuous variables were assessed with the paired *t* test if normally distributed, otherwise, the Wilcoxon signed-rank test was used. Differences between unpaired continuous variables were assessed with the unpaired *t* test if normally distributed, and with the Mann-Whitney *U* test if not normally distributed. Categorical variables were reported as frequencies and percentages and were analyzed using the chi-square or Fischer exact test. Kaplan-Meier analysis was performed to estimate cumulative survival free of MACE at 1-year follow-up and the results were compared between groups using the log-rank test. Statistical analysis was performed with SPSS for Windows version 25.0 (IBM, Armonk, New York). All tests were two-sided, and a p <0.05 was considered statistically significant.

Table 1
Baseline demographics and medical history

	Overall n = 454	Men n = 342	Women n = 112	p Value
Age, years	73±9.0	723±9.0	74±9.2	0.303
Diabetes	152 (34%)	115 (34%)	37 (33%)	0.787
Hypertension	315 (69%)	237 (69%)	78 (70%)	0.789
Hypercholesterolemia	238 (52%)	178 (52%)	60 (54%)	0.874
Family history of CAD	115 (25%)	81 (24%)	34 (30%)	0.203
Chronic kidney disease (GFR<60 ml/min/1.73 m^2)	138 (30%)	98 (29%)	40 (36%)	0.138
SYNTAX score	22±14	24±14	17±10	**<0.001**
Fluoroscopic calcification (n = 322)				0.772
Not possible	46 (14%)	33 (13%)	13 (18%)	
None/mild	20 (6%)	15 (6%)	5 (7%)	
Moderate	25 (8%)	20 (8%)	5 (7%)	
Severe	231 (72%)	181 (73%)	50 (69%)	
Left ventricular ejection fraction (n = 345)	44±13	45±13	41±15	0.420
Good (>50%)	218 (63%)	166 (63%)	52 (63%)	
Reasonable (30-50%)	93 (27%)	72 (27%)	21 (26%)	
Poor (20-30%)	17 (5%)	14 (5%)	3 (4%)	
Very poor (<20%)	3 (1%)	2 (1%)	1 (1%)	
Unknown	14 (4%)	9 (3%)	5 (6%)	
Smoking history, n (%)	194 (43%)	147 (43%)	47 (42%)	0.678
Previous stroke, n (%)	71 (16%)	48 (14%)	23 (21%)	0.108
Previous MI, n (%)	170 (37%)	141 (41%)	29 (26%)	**0.004**
Previous PCI, n (%)	211 (47%)	162 (47%)	49 (44%)	0.473
Previous CABG, n (%)	87 (19%)	76 (22%)	11 (10%)	**0.004**
Clinical presentation				**0.014**
ACS	202 (45%)	141 (41%)	61 (54%)	
CCS	252 (56%)	201 (59%)	51 (46%)	

ACS = acute coronary syndrome; CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CCS = chronic coronary syndrome; MI = myocardial infarction; PCI = percutaneous coronary intervention.

Table 2
Lesion and procedural characteristics

	Overall n = 477	Men n = 362	Women n = 115	p Value
Target vessel				
LM	57 (12%)	43 (12%)	14 (12%)	0.932
LAD	212 (44%)	162 (45%)	50 (44%)	0.811
LCx	75 (16%)	62 (17%)	13 (11%)	0.135
RCA	169 (35%)	120 (33%)	49 (43%)	0.065
Bypass	4 (1%)	3 (1%)	1 (1%)	1.000
Lesion characteristics				
Bifurcation	111 (23%)	87 (24%)	24 (21%)	0.484
Aorta-ostial	96 (20%)	63 (17%)	33 (29%)	**0.009**
CTO	33 (7%)	29 (8%)	4 (4%)	0.137
Long-segment	306 (64%)	239 (66%)	67 (58%)	0.131
In-stent	168 (35%)	126 (35%)	42 (37%)	0.737
IVL				
Balloon diameter, mm	3.5±0.5	3.5±0.5	3.5±0.5	0.075
Number of pulses	80 (60-80)	80 (60-80)	80 (50-80)	0.626
Pre-dilatation	441 (93%)	335 (93%)	106 (92%)	1.000
Post-dilatation	448 (94%)	341 (94%)	107 (93%)	0.818
After stenting (bail-out)	81 (17%)	60 (17%)	21 (18%)	0.675
ICI performed	249 (52%)	197 (54%)	52 (45%)	0.080
Pre-IVL	186 (39%)	150 (41%)	36 (31%)	0.052
IVUS	167 (35%)	131 (36%)	36 (31%)	0.339
OCT	22 (5%)	20 (6%)	2 (2%)	0.124
Post-IVL	206 (43%)	162 (45%)	44 (38%)	0.221
IVUS	184 (39%)	142 (39%)	42 (37%)	0.604
OCT	22 (5%)	19 (5%)	3 (3%)	0.313
Other plaque modification technique used	77 (16%)	59 (16%)	18 (16%)	1.000
Pre-IVL	69 (15%)	53 (15%)	16 (14%)	0.847
RA	62 (13%)	48 (13%)	14 (12%)	0.763
Cutting balloon	5 (1%)	4 (1%)	1 (1%)	1.000
Scoring balloon	1 (0.2%)	0	1 (1%)	0.241
OPN balloon	1 (0.2%)	1 (0.3%)	0	1.000
Post-IVL	9 (2%)	7 (2%)	2 (2%)	1.000
RA	5 (1%)	4 (1%)	1 (1%)	1.000
Cutting balloon	1 (0.2%)	0	1 (1%)	0.241
OPN balloon	3 (0.6%)	3 (1%)	0	1.000
Treatment after IVL				
Stent implantation	369 (77%)	281 (78%)	88 (77%)	0.806
Drug-coated balloon	34 (7%)	27 (8%)	7 (6%)	0.835
Procedural time, min	95±83	96±92	89±41	0.408
Fluoroscopy time, min	29±19	30±19	27±17	0.288
Contrast volume, ml	186±77	187±77	185±77	0.857

CTO = chronic total occlusion; ICI = intracoronary imaging; IVL = intravascular lithotripsy; IVUS = intravascular ultrasound; LAD = left anterior descending artery; LCx = left circumflex artery; LM = left main; OCT = optical coherence tomography; OPN = ultra-high pressure balloon; RA = rotational atherectomy; RCA = right coronary artery; SVG = saphenous venous graft.

Results

In total, 454 patients (age 73 ± 9.0 years) were treated with IVL, of which 342 (75%) were men and 112 (25%) were women. Overall, patient characteristics and medical history are listed in Table 1, and were mostly comparable between the 2 groups. However, the SYNTAX score was higher in men (24 ± 14 in men vs 17 ± 10 in women; p <0.001), whereas more women presented with ACS (41% in men vs 54% in women; p = 0.014). The lesion and procedural characteristics (n = 477) are listed in Table 2. The left anterior descending artery (LAD) was the most frequently treated target lesion site in both groups (45% in men vs 44% in women; p = 0.811) with left main (LM) involvement of 12% in both (p = 0.932). No statistically significant differences were found between men and women regarding the treatment of most target lesion subtypes. However, aorta-ostial lesions were observed more in women (17% in men vs 29% in women; p = 0.009).

Procedural characteristics were all comparable between men and women. The mean IVL balloon diameter was 3.5 ± 0.5 mm and a median of 80(60 to 80) pulses was delivered. Noncompliant balloon (NCB) predilatation and postdilatation were performed in almost all lesions (respectively 93% and 94%). In addition, plaque modification techniques were performed in 77 lesions (16%), mostly before IVL (n = 69, 15%) with rotablation (n = 61, 13%) being the most used technique. Stents were implanted in 369 target lesions (77%), whereas drug-coated balloon therapy was performed in 34 (7%).

Table 3
Intracoronary imaging analysis comparison between men and women

	Men n = 362	Women n = 115	p Value
Pre IVL			
RVD, mm	4.1±0.6	4.2±0.6	0.179
RVA, mm^2	13±3.9	14±4.3	0.270
Minimum LD, mm	2.0±0.6	1.9±0.5	0.400
Minimum LA, mm^2	4.1±2.2	3.7±1.3	0.327
Diameter stenosis, (%)	50±14	54±14	0.200
Area stenosis, (%)	68±16	71±14	0.268
MSA, mm^2	5.3±2.3	5.2±1.7	0.834
Stent expansion, (%)	42±17	41±16	0.787
Eccentricity index	0.19±0.13	0.15±0.12	0.221
Calcium angle, degrees	360 (231-360)	360 (234-360)	0.919
Post IVL			
RVD, mm	4.1±0.6	4.2±0.7	0.923
RVA, mm^2	14±3.7	14±4.8	0.813
Minimum LD, mm	3.2±0.5	3.3±0.6	0.554
Minimum LA, mm^2	9.6±2.6	9.5±2.7	0.848
Diameter stenosis, (%)	23±10	21±10	0.415
Area stenosis, (%)	28±14	29±13	0.843
MSA, mm^2	9.7±2.6	9.5±2.7	0.760
Stent expansion, (%)	72±15	72±13	0.984
Eccentricity index	0.16±0.10	0.15±0.12	0.233

IVL = intravascular lithotripsy; minimum LA = minimum lumen area; minimum LD = minimum lumen diameter; MSA = minimum stent area; RVA = reference vessel area; RVD = reference vessel diameter.

ICI was performed in 249 (52%) target lesions, with a nonsignificant trend toward higher usage in men (54% in men vs 45% in women; p = 0.080). Pre-IVL and post-IVL (and stenting) values were comparable between men and women (Table 3), whereas the overall minimum LD (p <0.001), minimum LA (p <0.001), DS (p <0.001) and AS (p <0.001) improved significantly after IVL therapy and stenting (Supplementary Table 1). QCA analysis was available in 408 (86%) lesions, n = 313 (86%) in men, n = 95 (83%) in women. Similar to ICI, pre-IVL, and post-IVL (and stenting) values were comparable between men and women (Supplementary Table 2), whereas significant improvements were observed in minimum LD (; p <0.001) and DS (; p <0.001) after IVL and stenting (Supplementary Table 1). The mean diameter gain for both men and women was 1.9 ± 0.9 mm (p = 0.819).

Notably, between groups there were comparable rates of device success (97% in men vs 98% in women; p = 1.000), technical success (90% in men vs 91% in women; p = 0.821), and procedural success (90% in men vs 88% in women; p = 0.749) (Table 4 and Figure 1). Overall, 29 (6%) complications occurred with a trend toward higher occurrence in women (n = 18, 5% in men vs n = 11, 10% in women; p = 0.087) (Figure 2). Abrupt vessel closure was significantly more frequent in women (n = 1, 0.3% in men vs n = 3, 3% in women; p = 0.047). IVL-related complications (2% in men vs 1% in women; p = 0.362) were observed in equal frequency and included 2 (0.4%) coronary dissections, 2 (0.4%) cases of hemodynamic instability (of which 1 (0.2%) required resuscitation), 1 (0.2%) case of abrupt vessel closure and 1 (0.2%) case of ventricular fibrillation, all successfully treated.

During a median follow-up of 365 (166 to 365) days, with complete 1-year follow-up currently present in 283 (62%) patients in this ongoing registry, MACE was observed in 37 (13%) (n = 26, 12% in men vs n = 11, 17% in women; p = 0.456). One-year MACE-free survival was comparable between sexes (p = 0.389) (Figure 3, Table 4). In-

Table 4
Procedural and clinical outcomes

	Overall n = 454	Men n = 342	Women n = 112	p Value
Procedural outcomes				
Device success	443 (98%)	333 (97%)	110 (98%)	1.000
Technical success <30%	411 (91%)	309 (90%)	102 (91%)	0.821
Procedural success <30%	405 (89%)	306 (90%)	99 (88%)	0.749
MACE				
In-hospital (n = 454)	10 (2%)	6 (2%)	4 (4%)	0.271
30 days (n = 324, 104)	16 (4%)	11 (3%)	5 (5%)	1.000
6 months (n = 280, 88)	31 (8%)	21 (8%)	10 (11%)	0.365
1 year (n = 217, 66)	37 (13%)	26 (12%)	11 (17%)	0.456

MACE = major adverse cardiovascular events.

hospital follow-up was present for all patients, in which adverse cardiovascular events occurred in 6 (2%) men and 4 (4%) women (p = 0.271). In-hospital events included 8 cardiac deaths (n = 4, 1% in men vs n = 4, 4% in women): 5 because of cardiogenic or hypovolemic shock, 2 sudden cardiac arrests, and 1 caused by an iatrogenic aortic root dissection after high-pressure postdilatation. None of these events were directly related to the IVL procedure. Additionally, 2 clinically driven target vessel revascularizations occurred: 1 emergency coronary artery bypass graft (CABG) for a coronary dissection caused by predilatation and 1 PCI for thrombus embolization.

Discussion

This study evaluated sex-related differences in the treatment and 1-year outcomes of calcified coronary lesions treated with IVL using data from a real-world, all-comers, international registry. The main findings of the study are (1) procedural efficacy and safety outcomes acutely and at 1-year follow-up after IVL were generally good and comparable between men and women; (2) clinical presentation differed between men and women, with women presenting more with ACS and aorta-ostial lesions; and (3) a nonsignificant trend toward higher complication and MACE was observed in women, which warrants further investigation.

Patient characteristics and medical history were generally comparable between men and women, including age and co-morbidities. However, men had a higher occurrence of previous MI's and CABG and a higher SYNTAX score, likely because of the earlier development and progression of atherosclerosis in men.[5,6] The observed similarities in age and co-morbidities in this study, differ from previous studies on sex-related differences in PCI and the sex-specific outcomes of the DISRUPT-CAD studies, where women were older and had more co-morbidities.[3–5,18,19,24] Notably, in this study significantly more women presented with ACS and aorta-ostial lesions, which were exclusion criteria in the DISRUPT-CAD studies. Therefore, the women who underwent IVL for CAC in this study represent a distinct cohort from those evaluated in earlier studies, potentially explaining the similarities in age and co-morbidities. This study thus enhances our understanding of sex-related differences in CAC treated with IVL, by evaluating its application across all indications in contemporary practice. Additionally, these similarities may reflect improvements in early detection and treatment of calcified CAD in women, although this has to be verified in larger prospective studies.

The lesion and procedural characteristics of the IVL treatment were largely comparable between sexes. Additionally, vessel sizes, including RVD on ICI, were similar. This is in contrast to earlier studies, where women had smaller vessel sizes as compared with men.[5] This difference may be partially attributed to a higher occurrence of aorto-ostial lesions in women. Considering the higher presentation with ACS and aorto-ostial lesions in women, which are associated with worse clinical outcomes, the women in this study appeared to present with higher-risk profiles than men.[25–27] This finding would support increased lesion assessment with ICI in women, despite observing a nonsignificant trend of lower ICI use in women in this study.

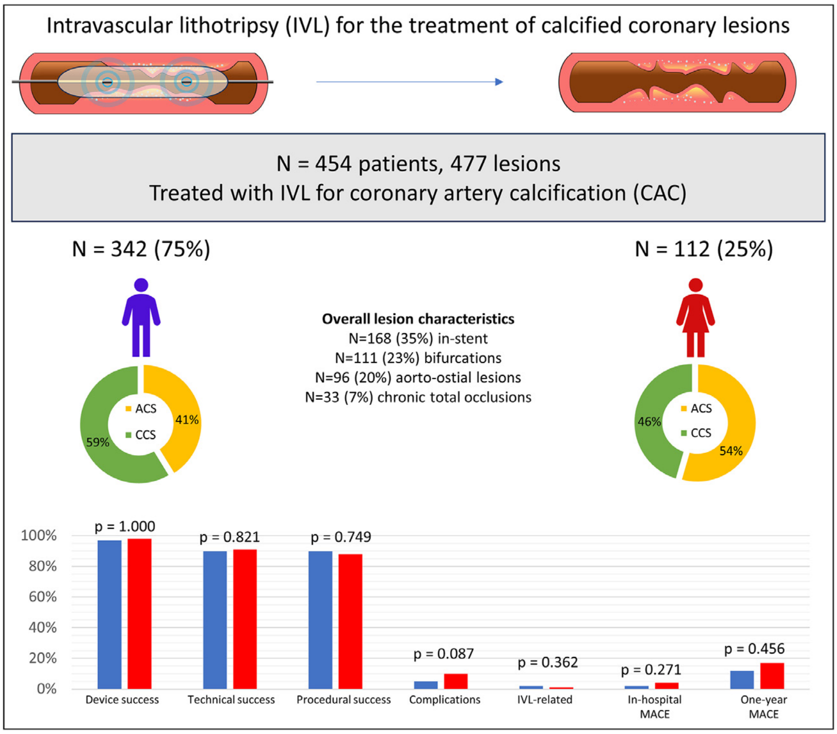

Figure 1. Comparison of 1-year procedural outcomes and cardiovascular events after intravascular lithotripsy between men and women. technical success = thrombolysis in myocardial infarction 3 flow and residual stenosis <30%.

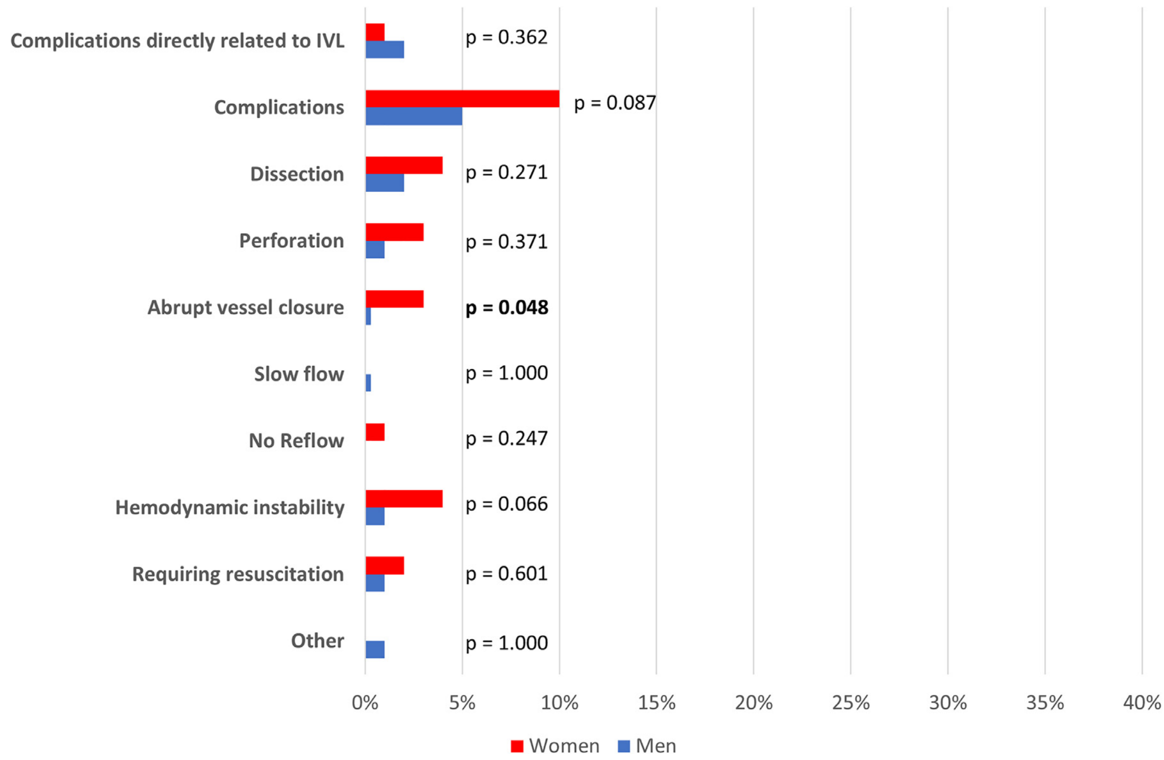

Figure 2. Sex-related differences in procedural complications

Despite the difference in clinical and anatomical presentation between men and women, procedural success rates were high and comparable, with similar luminal gain achievement. Additionally, IVL-related complication rates and MACE rates were low and consistent across both groups, although comparisons of clinical outcomes should be interpreted with caution because of the limited sample size of women and the low event rates observed. A nonsignificant trend toward a higher overall complication rate was observed in women (10%) compared with men (5%). This aligns with earlier studies assessing sex differences in outcomes after regular PCI and PCI with the deployment of other calcium modification techniques like rotational atherectomy, which both reported higher levels of complications in women.[14,24] This suggests that women may have a higher baseline complication risk compared with men, potentially in part because of higher arterial stiffness after menopause.[28] Considering the trend in higher complication rates and the observed higher risk profile of women in this study, interventional cardiologists should consider a cautious (more ICI-guided) approach, utilizing ICI more frequently in women, to prevent complications. Nevertheless, the overall complication rate of 10% in women treated with IVL is lower than the 13% complication rate reported in a study evaluating women treated with RA in a similar patient population in terms of age, comorbidities, and medical history.[14] This suggests that IVL may offer advantages for women in certain clinical scenarios, however, larger prospective studies are necessary that directly compare IVL with other calcium modification techniques in women.

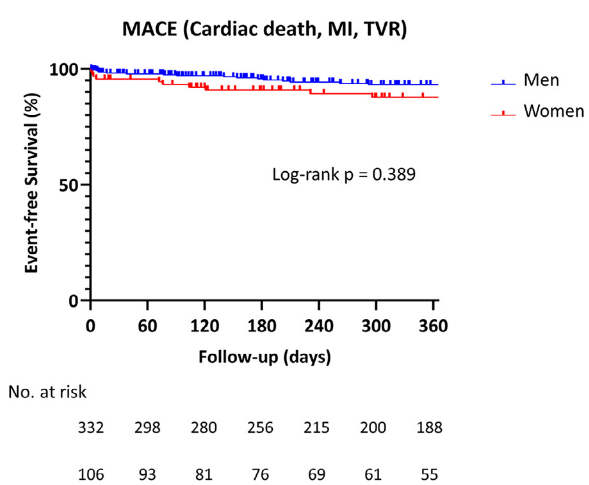

Figure 3. One-year major adverse cardiovascular events-free s.urvival of men and women treated with intravascular lithotripsy.

TVR = target vessel revascularization.

Similar to the success and IVL-related complication rates, the in-hospital (2%) and 1-year (13%) MACE rates after IVL therapy were low and comparable between men and women. Specifically, the MACE rates were 12% in men and 17% in women, both of which are lower than the observed 24% MACE rate after RA in the ROTAXUS trial, which involved a similar patient population but included more stable patients than the present study.[29]

Overall, these results suggest that IVL is a safe and effective treatment option for CAC in all-comers clinical practice for sexes, potentially closing the gap between treatment outcomes for CAC in men and women. However, there is still room for improvement, as future studies, such as equity in modifying plaque of women with undertreated calcified coronary artery disease (EMPOWER CAD), should focus on women-specific characteristics of CAC and strategies to further enhance outcomes for women.[30]

This study has several limitations that should be considered. First of all, it has an observational design. Additionally, the comparison of clinical outcomes between men and women has to be interpreted with caution because of the limited sample size of women and the low event rates observed. Larger future studies are needed to confirm or refute the observed trends. Additionally, the decisions regarding the timing of IVL, the utilization of high-pressure predilatation and postdilatation, the placement of supplementary stents, and the use of ICI for procedural optimization were left to the operator's discretion. The lack of routine use of ICI for all patients before and after IVL hindered the assessment of the standalone treatment effect of IVL.

In conclusion, despite the variations in clinical presentation and lesion types, IVL showed high success rates, low IVL-related complication rates, and MACE rates at discharge and 1-year follow-up in both men and women, although clinical outcomes have to be interpreted with caution. IVL seems to be safe and effective for both sexes across various clinical and anatomical scenarios.

Declaration of competing interest

The Department of Cardiology of the Leiden University Medical Center received unrestricted research grants from Abbott Vascular, Bayer, Biotronik, Boston Scientific, Edwards Lifesciences, GE Healthcare (Little Chalfont, United Kingdom), and Medtronic. B.E.P.M. Claessen reports relations with Sanofi, Philips, Amgen, Boston Scientific Corp, and AbioMed Inc. that include consulting or advisory. TNE Vossenberg received consultancy fees from Boston Scientific and Cardiac Dimensions. Dr Kefer has served as a proctor for Abbott. F. van der Kley received consultancy fees from Edwards Lifesciences and Abbott Vascular. J.M. Montero received a research grant from Shockwave Medical and speaker fees from Abiomed, Boston Scientific, and Penumbra Inc. The remaining authors have no conflicts of interest to declare.

CRediT authorship contribution statement

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2024.11.002.

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