Increased risk of aortic valve stenosis in patients with psoriasis: a nationwide cohort study†

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Aim
Psoriasis is a chronic inflammatory disease associated with increased risk of cardiovascular disease including atherosclerosis. The pathogenesis of aortic valve stenosis (AS) also includes an inflammatory component. We therefore investigated the risk of AS in patients with psoriasis compared with the general population in a nationwide cohort.

Methods
The study comprised the entire Danish population aged ≥18 years followed from 1 January 1997 until diagnosis of AS, 31 December 2011, or death. Information on comorbidity, concomitant medication, and socioeconomic status was identified by individual-level linkage of administrative registers. Incidence rates for AS were calculated and incidence rate ratios (IRRs) adjusted for age, gender, calendar year, comorbidity, medications, and socioeconomic status, were estimated in Poisson regression models.

Results
A total of 5,107,624 subjects were eligible for analysis. During the study period, we identified 58,747 patients with mild psoriasis and 11,918 patients with severe psoriasis. The overall incidence rates for AS were 8.09, 16.07, and 20.08 per 10,000 person-years for the reference population (48,539 cases [mean follow-up 12.3 years]), mild psoriasis (509 cases [mean follow-up 6.2 years]), and severe psoriasis (99 cases [mean follow-up 5.4 years]), respectively. Correspondingly, the fully adjusted IRRs for AS were markedly increased in patients with psoriasis with IRR 1.22 (95% confidence interval [CI] 1.12–1.33) and IRR 1.61 (CI 1.32–1.96) for subjects with mild and severe disease, respectively.

Conclusion
In a nationwide cohort, psoriasis was associated with a disease severity-dependent increased risk of AS. The mechanisms underlying this novel finding require further study.

Keywords
Aortic valve stenosis • Psoriasis • Cardiovascular risk • Inflammation • Epidemiology

Translational perspectives
Psoriasis is a chronic systemic inflammatory disease associated with a range of comorbidities including cardiovascular diseases. It is possible that this increased risk is driven by an overlap of inflammatory mechanisms. The current results suggest that patients with psoriasis have a disease severity-dependent increased risk of AS that is not explained by traditional cardiovascular risk factors. Additional studies are needed to define the mechanisms underlying the association between psoriasis and AS.

Introduction
Psoriasis is a common chronic inflammatory disease estimated to affect between 0.9 (USA) and 8.5% (Norway) of the world’s population.1 Psoriasis appears to be an independent risk factor for ischaemic heart disease and shares inflammatory mechanisms with atherosclerosis.2–8 Aortic valve stenosis (AS) is one of the most frequent valvular diseases with prevalence increasing from 0.2% in...
adults between 50 and 59 years to 9.8% in octogenarians, and is associated with major morbidity, mortality, and societal economic burden. Aortic valve stenosis shares risk factors with atherosclerosis (e.g. smoking, hypertension, diabetes, and hypercholesterolemia) and the pathogenesis of AS also has a number of similarities with atherosclerosis with active remodelling processes in which inflammation plays an important role. From this perspective, a link between AS and psoriasis due to shared inflammatory pathways and overlap of classical cardiovascular risk factors may exist. We therefore used Danish nationwide registers to determine the risk of AS in patients with psoriasis compared with the general population.

Methods

Data sources
We conducted a population-based nationwide cohort study of Danish prospectively recorded administrative databases. All Danish citizens are allocated an individual and permanent personal civil registration number at birth, which allows linkage of data across the respective registers on an individual level.

Data on all dispensed drug prescriptions from Danish pharmacies were retrieved from National Prescription Registry, where all information is recorded according to the Anatomical Therapeutical Chemical (ATC) classification system since 1995. This register has a high accuracy due to the partial compensation of drug expenses by the government, which ensures complete registration of all dispensed prescriptions.

Information on morbidity was obtained from the Danish National Patient Register, which holds data on all hospital admissions, out-patient consultations, diagnoses, and procedures, (recorded since 1978) listed according to the international classification of diseases (ICD). The Central Population Register and National Causes of Death Registry were utilized to identify all deaths and causes of deaths. An age-standardized index of socioeconomic status was defined as the individual average yearly gross income during a 5-year period before study start. The present study was conducted and reported in line with the guidelines for cohort study as defined in the Strengthening the Reporting of Observational Studies in Epidemiology recommendations.

Study population
The entire Danish population aged ≥18 years, starting from 1 January 1997 was followed until diagnosis of AS, 31 December 2011, migration or death. Patients with psoriasis were identified by claimed prescriptions for topical vitamin D derivatives (ATC code D05AX). To ensure persistent medical treatment for psoriasis, patients were included when claiming their second prescription for these agents which are not accessible over the counter in Denmark and are used only for psoriasis as first-line treatment. Patients were classified as having severe psoriasis at the time of their third diagnosis, i.e. hospitalization or out-patient consultation for psoriasis (ICD-10 L40) or psoriatic arthritis (M070–M073). This identification and classification method for psoriasis and psoriasis severity has been used and validated in previous studies. Patients with dispensed prescriptions for vitamin D derivatives prior to study start and patients with a history of psoriasis and/or AS were excluded from the study at baseline.

Pharmacotherapy
Baseline treatment was defined by dispensed prescriptions up to 6 months prior to study inclusion date with the following medications: β-blockers (C07), loop diuretics (C03C), thiazides (C03AA), angiotensin-converting enzyme inhibitors/angiotensin 2 receptor blockers (ACEI/ARB) (C09), calcium-channel blockers (C08), vitamin K antagonists (B01AA), digoxin (C01AA), acetylsalicylic acid (B01AC06), anti-diabetic drugs (A10), platelet inhibitors (B01AC), cholesterol-lowering drugs (C10A), glucocorticoids (H02AB), and methotrexate (L01BA01).

Outcome
The main outcome for the study was new-onset AS, determined by first in- or out-patient diagnosis for non-rheumatic AS (ICD-10 codes: I350, 1352, and ICD-8 codes 42 410, 42 418, and 42 419) as recorded in the National Patient Registry.

Statistical analysis
All statistical analyses were performed with the SAS statistical software version 9.2 (SAS Institute Inc. Cary, NC, USA) and STATA software version 11.0 (StataCorp, College Station, TX, USA).

Baseline characteristics are presented as frequencies and percentages for categorical variables and as means with standard deviations for continuous variables. Age and psoriasis were included as time-dependent variable, i.e. subjects were only considered at risk from the time they met the criteria for psoriasis. Calendar year was also included as time-dependent covariate, where bands were split in 1-year periods after 1 January 1997. Comorbidity was continuously updated throughout study follow-up and evaluated for diabetes (ICD-10 codes E10–E14 and ICD-8 codes 250), atrial fibrillation (ICD-10 code I48 and ICD-8 code 4279), hypertension (ICD-10 codes I10–I15), vascular disease (ICD-10 codes I21–I22, I70, and ICD-8 codes 410–440), thromboembolism (ICD-10 codes I26, I63, I64, I74, G458, G459, and ICD-8 codes 433-438, 444, and 450), and renal disease (N03, N04, N17–N19, 112, 113, R34 and ICD-8 codes 582–586, 588). Time-dependent multivariable Poisson regression models adjusted for confounding factors including age, gender, calendar year, comorbidity, socioeconomic status, and concomitant medications were fitted to estimate incidence rate ratios (IRRs) for AS. Incidence rates are presented as events per 10 000 person-years at risk.

Sensitivity analyses
Patients with cardiovascular disease, e.g. atherosclerotic disease, are likely to undergo increased medical evaluation, including cardiac auscultation and medical tests such as echocardiography. Consequently, detection of AS may be favoured by more frequent in- or out-patient examination in this population group. To determine the potential detection bias, we therefore performed a sensitivity analysis where all subjects with atherosclerotic disease, i.e. atherosclerotic heart disease (ICD-10 code I251), myocardial infarction (ICD-10 codes I21, I22), stroke (ICD-10 codes I61, I63, and I64), and atherosclerotic vascular disease (ICD-10 code I70) were excluded at study baseline. We also continuously censored the subjects who developed atherosclerosis throughout the study period. Likewise, to address the impact of surveillance bias caused by increased healthcare consumption associated with our definition of psoriasis, we also performed analyses with alternative inclusion criteria for psoriasis, i.e. where patients with psoriasis were identified by the first claimed prescription for vitamin D derivatives and reclassified as having severe psoriasis at the time of their first in- or out-patient hospitalization with the psoriasis diagnosis. These alternative criteria for definition of psoriasis and psoriasis severity are associated with considerably less frequent physician and hospital visits compared with the primary psoriasis definition. Finally, we estimated age-stratified incidence rates of AS per 10 000 person-years in patients with psoriasis aged 18–40, 40–65, and 65–90 years, respectively.

For all analyses, a two-tailed P-value <0.05 was considered statistically significant and 95% confidence intervals (CIs) were also presented.
Results

Baseline characteristics

The study included a total of 5,107,624 Danish citizens, aged ≥18 years from 1 January 1997 to 31 December 2011. Subjects with a history of psoriasis (n = 14,061) and AS (n = 4,166) were excluded from the analysis at study baseline. In the course of the study period, 58,747 subjects with mild psoriasis and 11,918 with severe psoriasis were identified. A flowchart of the study population selection is shown in Figure 1. Compared with the reference population, patients who developed psoriasis had similar use of cardiovascular medications and comparable comorbidity at baseline (Table 1). The mean duration from psoriasis diagnosis (according to our study criteria) to new-onset AS was 10.2, 6.7, and 5.7 years for the reference population, mild psoriasis, and severe psoriasis, respectively.

Risk of aortic valve stenosis

The overall incidence rates for AS were 8.09 (CI 8.02–8.17), 16.07 (CI 14.73–17.52), and 20.08 (CI 16.50–24.45) per 10,000 person-years for the reference population (48,539 cases [mean follow-up 12.3 years]), mild psoriasis (509 cases [mean follow-up 6.2 years]) and severe psoriasis (99 cases [mean follow-up 5.4 years]), respectively. The multivariable Poisson regression analyses, adjusted for age, gender, and calendar year confirmed psoriasis severity-dependent elevated IRRs for AS in patients with psoriasis compared with the reference population, i.e. IRRs 1.31 (CI 1.20–1.43) and 1.74 (CI 1.43–2.13) for mild and severe psoriasis, respectively. The significantly increased risk of AS associated with psoriasis persisted in the fully adjusted statistical models controlling for age, gender, calendar year, comorbidity, concomitant medications, and socioeconomic status (Table 2, Figure 2).

Figure 1  Flow chart of selection of study population.

Sensitivity analyses

Exclusion of patients with atherosclerotic disease prior to study start together with censoring of patients who developed atherosclerotic disease during study period did not attenuate the observed association between psoriasis and risk of AS (Table 2). Indeed, in these analyses patients with psoriasis had markedly increased age-, gender-, and calendar year-adjusted IRRs for AS, that were comparable with the results of the primary analyses. When we altered the criteria for definition of psoriasis and psoriasis severity, we identified 90,900 patients with mild psoriasis and 25,094 patients with severe psoriasis. Again the results were similar to the primary analyses, with increased age-, gender-, and calendar year-adjusted IRRs for AS in patients with mild (IRR 1.26 [CI 1.17–1.36]) and severe (IRR 1.54 [CI 1.34–1.77]) psoriasis, respectively. The age-stratified rates of AS per 10,000 person-years were increased for individuals with psoriasis in all age strata, and were highest for patients aged ≥65 years with severe psoriasis compared with the reference population (Table 3).

Discussion

The present study is, to the best of our knowledge, the first to assess the risk of AS in patients with psoriasis compared with the general population. The main result was that psoriasis was associated with increased risk AS independent of age, gender, comorbidity, and socioeconomic status. Importantly, the risk of AS demonstrated a dose–response relationship with respect to psoriasis severity. Psoriasis is a T helper 1 (Th1)- and Th17 cell-driven immune-mediated disease associated with a range of comorbidities including cardio-metabolic diseases.2–8 Indeed, previous studies have indicated that psoriasis is an independent risk factor for atherosclerotic disease and persistent systemic inflammation is likely to contribute to this association.2,5,17,19 Although the pathogenesis of AS is poorly understood, it has traditionally been considered as a degenerative process that shares clinical risk factors with atherosclerosis.9,11,20 However, evolving evidence has clearly suggested that AS is an active cellular process, where inflammation play an important contributory role.7,11,12,20 For example, the presence of T lymphocytes and elevated levels of inflammatory mediators, e.g. tumour necrosis factor (TNF-α), have been reported in stenotic aortic valves and appear to correlate with the progression rate of AS.12,13,21 In addition, circulating levels of C-reactive protein and inflammatory adhesion molecules may be increased in patients with AS and recent studies with use of positron emission tomography have further corroborated that aortic valve inflammation is associated with AS severity.22–24 TNF-α is also considered to be an important inflammatory mediator in pathogenesis of psoriasis adding weight to the hypothesis that coincident inflammatory mechanisms and genetic predispositions may explain, in part, the association between psoriasis and AS. Moreover, in addition to hypertension being more prevalent in patients with psoriasis, the chronic inflammatory state in psoriasis has been associated with increased arterial stiffness and endothelial dysfunction (both of which potentially amenable to treatment with anti-TNF-α agents) which may contribute to increased aortic valve haemodynamic stress leading to AS.25–27 Large systematic cardiac imaging studies of unselected patients...
with psoriasis have not been reported, but in the as yet largest studies with echocardiography of patients with psoriasis without clinical evidence of cardiovascular disease, increased rates of aortic valve sclerosis or subclinical AS was not observed compared with controls, albeit that subclinical left ventricular dysfunction was more prevalent.28,29 Increased aortic root diameter that correlated with psoriasis severity and platelet activation was also recently reported, suggesting the intriguing possibility that this may represent an early reflection of the more systemic nature of AS, e.g. with effects on both the left ventricle and the downstream systemic vasculature.30 Importantly, we and others have reported that the risk of congestive heart failure is increased in patients with

Table 1  Baseline characteristics of the study population

<table>
<thead>
<tr>
<th></th>
<th>Reference population (n = 5 036 959)</th>
<th>Mild psoriasis (n = 58 747)</th>
<th>Severe psoriasis (n = 11 918)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) age (years)</td>
<td>41.9 (19.9)</td>
<td>44.1 (16.5)</td>
<td>42.5 (15.1)</td>
</tr>
<tr>
<td>Men (%)</td>
<td>2 482 799 (49.3)</td>
<td>28 656 (49.0)</td>
<td>5629 (47.2)</td>
</tr>
<tr>
<td>Mean (SD) socioeconomic status</td>
<td>2.0 (1.4)</td>
<td>2.5 (1.3)</td>
<td>2.5 (1.2)</td>
</tr>
<tr>
<td>Comorbidity (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular disease</td>
<td>49 170 (1.0)</td>
<td>534 (0.9)</td>
<td>93 (0.8)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>34 962 (0.7)</td>
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</tr>
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<td>Renal disease</td>
<td>5209 (0.1)</td>
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<td>14 (0.1)</td>
</tr>
<tr>
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<td>Diabetes mellitus</td>
<td>38 816 (0.8)</td>
<td>413 (0.7)</td>
<td>109 (0.9)</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td>50 387 (1.0)</td>
<td>415 (0.7)</td>
<td>76 (0.6)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>40 321 (0.8)</td>
<td>492 (0.8)</td>
<td>140 (1.2)</td>
</tr>
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<td>Comorbidity (%)</td>
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<td>492 (0.8)</td>
<td>140 (1.2)</td>
</tr>
</tbody>
</table>

Table 2  Risk of aortic valve stenosis associated with psoriasis

<table>
<thead>
<tr>
<th></th>
<th>Incidence rate ratio for AS</th>
<th>95% confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted for age, sex, and calendar year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild psoriasis</td>
<td>1.31</td>
<td>1.20–1.43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severe psoriasis</td>
<td>1.74</td>
<td>1.43–2.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adjusted for age, sex, calendar year, comorbidity, medications, and socioeconomic status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild psoriasis</td>
<td>1.22</td>
<td>1.11–1.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severe psoriasis</td>
<td>1.61</td>
<td>1.32–1.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adjusted for age, sex, and calendar year (censored for subjects who developed atherosclerotic diseasea)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild psoriasis</td>
<td>1.31</td>
<td>1.20–1.43</td>
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</tr>
<tr>
<td>Severe psoriasis</td>
<td>1.77</td>
<td>1.45–2.15</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin 2 receptor blocker; COPD, chronic obstructive pulmonary disease.

with psoriasis have not been reported, but in the as yet largest studies with echocardiography of patients with psoriasis without clinical evidence of cardiovascular disease, increased rates of aortic valve sclerosis or subclinical AS was not observed compared with controls, albeit that subclinical left ventricular dysfunction was more prevalent.28,29 Increased aortic root diameter that correlated with psoriasis severity and platelet activation was also recently reported, suggesting the intriguing possibility that this may represent an early reflection of the more systemic nature of AS, e.g. with effects on both the left ventricle and the downstream systemic vasculature.30 Importantly, we and others have reported that the risk of congestive heart failure is increased in patients with
psoriasis and the contribution of AS to this finding clearly requires further study.31–33

Study strengths and limitations

The major strengths of the present study include the use of prospectively recorded nationwide data, complete follow-up, adjustment for important confounding factors, and use of validated measures of exposure and endpoints. Due to a government-financed free of charge and readily accessible health care for all Danish inhabitants, the risk of selection bias related to e.g. gender, age, health insurance, and socioeconomic status was evaded. Furthermore, inclusion of the entire adult Danish population, and adjustment for continuously updated comorbidity at baseline reduced the potential for surveillance bias. Exclusion of subjects with prevalent psoriasis and/or AS at the study start ensured a more exact allocation of time at risk for the study population. Our results were also strengthened by the psoriasis severity-dependent increased risk of AS and this association both remained statistically significant after adjustments for potential confounders and in sensitivity analyses aimed at reducing surveillance bias, respectively.

When interpreting the results, there are certain limitations to be acknowledged. We used number of hospitalizations to classify psoriasis severity, which may have increased the surveillance bias and thus decreased the threshold for detection of the study outcome in the psoriasis population. We addressed this limitation by adjusting for important confounding factors including concomitant medication and comorbidities, and by conducting sensitivity analyses, respectively, as described above. Also, the use of claimed prescriptions of vitamin D derivatives to define mild psoriasis, does not account for patients who may have received other topical therapies or ultraviolet light treatment for psoriasis. However, this method of identifying mild psoriasis has previously been validated and it was demonstrated that ≏75% of the Danish population with psoriasis was prescribed with vitamin D derivatives as first-line treatment.17 Hence, bias related to a possible misclassification is expected to be minor and would arguably favour the null hypothesis. Aortic valve stenosis is a condition that progresses slowly over time and the prevalence has been reported to be 0.2% in subjects aged 50–59 years, increasing with age up to 9.8% in individuals 80–89 years of age.10 To determine the impact of age on the association between psoriasis and AS, we therefore performed an age-stratified

Table 3  Age-stratified incidence rates with 95% confidence intervals per 10 000 person-years of aortic valve stenosis

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Reference population</th>
<th>Mild psoriasis</th>
<th>Severe psoriasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>18–40</td>
<td>0.65 (0.62–0.68)</td>
<td>1.13 (0.67–1.91)</td>
<td>5.49 (3.04–9.92)</td>
</tr>
<tr>
<td>40–65</td>
<td>8.28 (8.16–8.40)</td>
<td>17.04 (15.13–19.20)</td>
<td>20.97 (16.02–27.45)</td>
</tr>
<tr>
<td>65–90</td>
<td>39.66 (39.20–40.13)</td>
<td>65.52 (57.50–74.67)</td>
<td>88.42 (63.49–123.15)</td>
</tr>
<tr>
<td>Over all crude IRs</td>
<td>8.09 (8.02–8.17)</td>
<td>16.07 (14.73–17.52)</td>
<td>20.08 (16.50–24.45)</td>
</tr>
</tbody>
</table>

Figure 2  Forest plot showing incidence rate ratios for aortic valve stenosis in psoriasis with 95% confidence intervals. **Estimates adjusted for: age, gender, and calendar year. Estimates adjusted for: age, gender, calendar year, comorbidity, medications, and socioeconomic status.
analysis, and consistent with our primary analysis we here also found incidence rates of AS to be significantly increased in subjects with mild and severe psoriasis, compared with the reference population. Notably, rates of AS increased exponentially with age and were highest for patients with severe psoriasis > 65 years of age. Among other limitations to be mentioned, the study was based on administrative registers and therefore did not include important clinical parameters such as echocardiographic data, blood pressure, smoking status, lipid profiles, and measures of obesity. Importantly, however, the multivariable adjustments for socioeconomic status, comorbidities, and a number of concomitant medications are likely to have covered some of these effects. Finally, the Danish population predominantly consists of Caucasians, which may limit the ability to generalize the results to other ethnicities.

**Conclusion**

The results indicate a disease severity-dependent increased risk of new-onset AS in patients with psoriasis independent of traditional risk factors. The findings expand the current knowledge of psoriasis as a clinically relevant risk factor for a range of cardiovascular diseases.

**Ethical statement**

Ethical approval is not required for register-based studies in Denmark.

**Authors contributions’**


**Acknowledgement**

Søren Lund Kristensen, MD, PhD, is acknowledged for support.

**Funding**

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**Conflict of interest:** L.S. has received honoraria as consultant and/or speaker for Abbott, Janssen-Cilag, MSD, Lilly, Novartis, Pfizer, and LEO Pharma. O.A. has received honoraria as speaker for Abbott, Pfizer, and Janssen-Cilag. P.R.H. has received honoraria as speaker for Abbvie and MSD. G.H.G. has received research grants from Bayer, Pfizer, AstraZeneca boehringer-ingelheim, and Bristol Meyer Squibb (BMS) and speaker honoraria from Pfizer, AstraZeneca, and BMS.

**References**


Optical coherence tomography follow-up after bioresorbable in metallic and bioresorbable in stenting: tackling in-stent restenosis in the era of bioresorbable vascular scaffolds

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This paper was guest edited by Brahmajee Nallamothu (University of Michigan; bnallamo@umich.edu).

A 63-year-old woman with stable angina underwent percutaneous coronary intervention of the left circumflex coronary artery (LCX) and the first obtuse marginal branch (OM1) with bilimimus-eluting stents (BES) with the V-stenting technique (Panels A and A'). Seven months later due to recurrent angina repeat coronary angiography was performed and revealed in-stent restenosis in the proximal segments of both BES. Subsequently, the OM1 lesion was diluted with a paclitaxel drug-coated balloon. The LCX stenosis was treated with an everolimus eluting bioresorbable vascular scaffold (BVS) extending into the proximal LCX segment (bioresorbable in metallic stenting) (Panels B and B'). A proximal edge dissection (Supplementary material online, Videos—OCT) was managed by implantation of another overlapping BVS in the proximal LCX (Panels J, J, K, and K'). Three months later the patient presented with recurrent chest pain. Coronary angiography documented in-stent restenosis in the proximal OM1 (Panel C) that was treated by implantation of a zotarolimus-eluting stent (ZES) extending from OM1 to the proximal LCX (Panel C') covering the BVS (metallic in bioresorbable stenting).

Twenty-seven months after the first intervention the patient reported atypical angina. Because of her extensive history, she was directly referred for coronary angiography, which showed all stents patent with excellent flow (Panel D). An optical coherence tomography was performed (Supplementary material online, Videos), which confirmed complete endothelialization, no restenosis, and well-expanded BVS in BES (Panels F and F') as well as ZES in BVS (Panels H and H').

Although these approaches need further evaluation through clinical trials, this case confirms the feasibility and efficacy of using metallic in bioresorbable and bioresorbable in metallic stenting for the treatment of in-stent restenosis with excellent endothelialization as documented by optical coherence tomography.

Supplementary material is available at European Heart Journal online.