**Temporal trends in in-hospital outcomes following unprotected left-main PCI: an analysis of 14,522 cases from British Cardiovascular Intervention Society database 2009-2017**

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**Abstract**

**Background:** Percutaneous coronary intervention is increasingly used as a treatment option for unprotected left main stem artery (uLMS-PCI) disease. However, whether patient outcomes have improved over time is uncertain. **Methods:** Using the United Kingdom national PCI database, we studied all patients undergoing uLMS-PCI between 2009 and 2017. We excluded patients who presented with ST-segment elevation, cardiogenic shock, and with an emergency indication for PCI. **Results:** Between 2009 and 2017, in the study-indicated population, 14,522 uLMS-PCI procedures were performed. Significant temporal changes in baseline demographics were observed with increasing patient age and comorbid burden. Procedural complexity increased over time, with the number of vessels treated, bifurcation PCI, number of stents used, and use of intravascular imaging and rotational atherectomy increased significantly through the study period. After adjustment for baseline differences, there were significant temporal reductions in the occurrence of peri-procedural MI (p<0.001 for trend), in-hospital MACCE (p<0.001 for trend), and acute procedural complications (p<0.001 for trend). In multivariable analysis examining the associates of in-hospital MACCE, whilst age per year (odds ratio (OR) 1.02 (95% confidence intervals 1.01-1.03)), female sex (OR 1.47 (1.19-1.82)), 3 or more stents (OR 1.67, 05% (1.02-2.67)), and patient comorbidity were associated with higher rates of in-hospital MACCE, by contrast use of intravascular imaging (OR 0.56 (0.45-0.70)), and year of PCI (OR 0.63 (0.46-0.87)) were associated with lower rates of in-hospital MACCE. **Conclusions:** Despite trends for increased patient and procedural complexity, in-hospital patient outcomes have improved after uLMS-PCI over time.

**Keywords:** Left main artery, percutaneous coronary intervention, national database, serial outcomes

**CLINICAL PERSPECTIVE**

**What is Known?**

* PCI is considered a reasonable alternative to CABG for some variants of unprotected left main stem disease (uLMS-PCI).
* Although it is recognised that uLMS-PCI is associated with higher complication rates, whether these rates have changed over time is unknown.

**What the Study Adds?**

* Between 2009 and 2017, we observed a significant trend for reductions in the rate of acute procedural complications and in-hospital MACCE in patients following uLMS-PCI.
* These data imply that over time, improved technologies and techniques combined with greater operator experience have improved patient outcomes following uLMS-PCI.

**List of abbreviations**

ACS – acute coronary syndrome

BCIS - British Cardiovascular Intervention Society

CABG – coronary artery bypass surgery

CVA – cerebrovascular disease

DES – drug-eluting stent

IVUS - intravascular ultrasound

LAD – left anterior descending

LMS - left main stem

LV – left ventricle

MACCE - major adverse cardiac or cerebrovascular events

MI – myocardial infarction

NYHA – New York Heart Association

PVD – peripheral vascular disease

PCI - percutaneous coronary intervention

uLMS-PCI – unprotected left main stem percutaneous intervention

**Introduction**

Percutaneous coronary intervention (PCI) is increasingly considered as a revascularisation strategy in certain anatomical and patient subsets of unprotected left main stem (uLMS) disease and is supported by the European Society of Cardiology 2018 Guidelines on myocardial revascularization and the AHA/ACC guidelines. (1-2) In recent years, the landscape of PCI has changed significantly, with major advances in interventional technologies and techniques. A previous analysis of the United Kingdom National PCI Database demonstrated a temporal increase in use of intravascular imaging, and that imaging use was strongly associated with improved 12-month survival.(3) Furthermore, several large randomised trials have informed interventional cardiologists as to optimal bifurcation strategies and side branch management.(4-6) Finally, as uLMS-PCI procedural volumes have increased over time, the effects of operator experience may also be associated with improved patient outcomes.(7) However, whether patient outcomes after uLMS-PCI have improved over time as a result of these changes is not well defined. Therefore, we used the United Kingdom National PCI Database to study temporal trends in in-hospital clinical outcomes following uLMS-PCI over a nine-year period.

**Methods**

*Study design and participants*

We analysed data from all patients undergoing uLMS-PCI in the United Kingdom between January 1st 2009 and December 31st 2017. We excluded patients who presented with ST-segment elevation, cardiogenic shock, and with an emergency indication for PCI. Thus, only patients without an immediate clinical need for uLMS-PCI were included in the analysis.

*Study setting and sources of data*

Data on PCI practice were obtained from the United Kingdom National PCI Audit dataset with the accuracy and quality of the BCIS dataset previously described.(8-9) The study was approved by the BCIS data extraction group and by Healthcare Quality Improvement Partnership (HQIP) research ethics groups. Because of the sensitive nature of the data collected for this study, requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to BCIS bcis@millbrookconferences.co.uk.

*Study definitions*

Study definitions were used as in the BCIS National PCI Audit dataset.(10) (Supplementary Appendix) Peri-procedural MI is defined in the BCIS dataset as “a rise of more than 3 times the 99th percentile of the upper reference limit of a troponin biomarker. If the troponin is not stable in at least 2 samples at baseline for at least 2 samples 6 hours apart, there are insufficient data to recommend criteria for the diagnosis of reinfarction.”

*Data analyses*

We examined the baseline characteristics of patients undergoing uLMS-PCI and tested for significance using Cochrane Armitage test for trends. Independent predictors of in-hospital MACCE after uLMS-PCI were evaluated using a multivariable logistic regression model to generate odds ratios, 95% confidence intervals and corresponding p-values. To select predictors to enter into the final multivariable model we used forward stepwise variable selection on the data and an inclusion criterion of p<0.1 (listed in Supplementary Appendix). To correct for missing values, we imputed missing data on baseline covariates using multiple imputations with chained equations to adjust for missing data (Supplementary Table 1). To evaluate if the temporal outcome trends were present after adjustment, we used a logistic regression and tested in the linear trend over time adjusted for the baseline covariates was significant or not.

**Results**

*uLMS-PCI crude numbers and trend in the United Kingdom 2009-2017*

Between 2009 and 2017 14,522 uLMS-PCI procedures were performed in the study indicated population. During the study period, annual uLMS-PCI volumes increased(Figure 1), and represented an increasing percentage of each yearly total PCI, rising from 1.8% of total PCI in 2009 and 3.4% in 2017 (Figure 2, right panel).

*Patient and procedural characteristics undergoing uLMS-PCI in the United Kingdom 2009-2017*

Significant changes were observed in patient age, female sex, and other comorbidity including diabetes mellitus, concomitant valvular heart disease, and number of diseased vessels over time (Table 1). There were also changes in the complexity of the uLMS-PCI procedure over time (Table 2). The number of vessels treated, LMS-PCI involving the LAD and circumflex, number of stents used, and use of tools such as intravascular imaging and rotational atherectomy all increased significantly through the study period. Use of glycoprotein inhibitors, LV support and femoral access decreased significantly over time (Table 2).

*Clinical and procedural outcomes after uLMS- in the United Kingdom 2009-2017*

The crude unadjusted outcomes after uLMS-PCI by procedure year are presented in Table 3 and Figure 2. The adjusted annual rate of clinical outcomes indexed to the first year of study (2009) are presented in Figure 3 and illustrate significant temporal reductions in the occurrence of peri-procedural MI (p<0.001 for trend), in-hospital MACCE (p<0.001 for trend), and acute procedural complication (p<0.001 for trend). The odds ratios for in-hospital major bleeding and in-hospital death did not change significantly over time. Subgroup analyses for in-hospital MACCE by sex (male vs female, p value for interaction=0.735) and clinical presentation (ACS vs stable angina p value for interaction=0. 979) do not differ significantly from the main study findings (Supplementary Tables 2 and 3).

In multivariable adjusted modelling examining the associates of in-hospital MACCE, age per year, female sex, peripheral vascular disease, 3 or more stents used, chronic kidney disease, ejection fraction and use of LV support were associated with higher rates of in-hospital MACCE (Figure 4). Use of intravascular imaging and year of PCI were associated with lower rates of in-hospital MACCE. Although there was a trend for potent DAPT to be associated with lower MACCE, this did not reach statistical significance (OR 0.82, 95% CI 0.83-1.07).

**Discussion**

Although there are many studies comparing uLMS-PCI and CABG, there is limited data on the temporal changes in patient outcomes after uLMS-PCI, and in particular in the CHIP population. Previously published series of outcomes after uLMS-PCI have limitations including that they examine other aspects of the interventional procedure such as access site or imaging, are non-contemporary, do not provide data on temporal trends in patient outcomes, or study only relatively short historical time-frames.(11-15) Two previously published larger scale studies have findings consistent with the current study. The IRIS-MAIN registry observed a reduction in MACCE rates after uLMS-PCI over time whilst.(16) Similarly, in an analysis of 4,085 uLMS-PCI cases from the Swedish Coronary Angiography and Angioplasty Registry (2005 to 2017), the 3-year major adverse cardiovascular and cerebrovascular event fell from 45.6% to 23.9% over the study period (17). However, the current study is much larger than any other previous study of uLMS-PCI outcome trends, reports procedures from a more contemporary time frame, and is the first analysis of uLMS-PCI outcomes in the “CHIP-indicated” population. The exclusion of patients with an emergency indication is important as a non-selected study population outcomes are likely to be heavily skewed by high event rates in the small subset of emergency patients.

In considering the mechanisms of the observed improved patient outcomes there may be several plausible explanations underpinning the improved in-hospital outcomes following uLMS-PCI over time. Previous studies have demonstrated that in the majority of cases, disease involving the left main artery extends into its distal bifurcation.(18) Many of the technical issues, such as accessing the circumflex, have largely been overcome by the advent of technologies such as angled microcatheters and techniques including dual lumen catheter wiring.(19) Emerging data on optimal interventional strategies to address bifurcation disease may also contribute to improved outcomes after uLMS-PCI over time. As with other studies of non-LMS PCI - including the Nordic Bifurcation Study and the British Bifurcation Coronary Study - data on uLMS-PCI suggest that where possible, a provisional stepwise stent strategy is at least as good as a planned 2-stent strategy in patients with bifurcation LMS disease .(6, 20) Where a 2-stent approach is considered necessary, a greater understanding of optimal planned bifurcation strategies derived from several randomised comparisons of bifurcation techniques such as the double kissing (DK)-crush technique and proximal stent optimisation (POT) may also underpin some of the improved outcomes observed.(21-22) Although in the current study, we observed an increase in the number of stents used over time, and an increased MACCE rate in cases where 3 or more stents were used, as this is observational data, the contribution of baseline disease likely confounds any association between the number of stents used and clinical outcomes. Additionally, an increase in the use of intravascular ultrasound imaging over time may improve outcomes driven by enhanced lesion coverage, optimal stent expansion, and appropriate stent sizing and apposition.(3, 23) Similarly, radial arterial access has previously been shown to be associated with improved outcomes after uLMS-PCI.(12) The increase in operator volume and experience is likely to be a major factor in improving patient outcomes after uLMS-PCI. A previous study of the UK national PCI database demonstrated improved patient outcomes with higher operator uLMS-PCI volumes, a volume-outcome effect not seen with PCI in general.(7) A similar association between higher uLMS-PCI operator volumes and improved patient outcomes was observed in a study of patients treated in a high-volume Chinese centre. (24) Finally, increases in more potent DAPT may be another explanation for improvements in outcomes over time. Although we observed a trend for lower MACCE rates when potent DAPT was used, this did not reach statistical significance, perhaps because of a lack of statistical power given the relatively infrequent use of potent DAPT until latter study years.

In considering the limitations of the present study, statistical methodology issues are discussed in the Supplementary Appendix. The measurement of post-procedure troponin evaluation is left up to the discretion of the individual operator and centre and thus there is likely to be variation in its measurement between centres. However, there has been no temporal change in the reporting of troponin values (97.7% field completion in 2009 vs. 98.3% in 2017, p=NS) implying that the data are not confounded by reporting bias over time. Additionally, the observation of a reduced peri-procedural MI over the study period is consistent with a lower rate of acute procedural complications and thus appears to be underpinned by biological plausibility. Additionally, the BCIS database does not capture details of anatomical data such as the location of disease with the LMS, complexity of lesions such as calcification or the presence, or type of distal LMS bifurcation disease. Therefore, we cannot provide detailed data on the relationship to the pattern of disease and outcomes over time, or indeed on the exact technical approach used to treat the LMS disease.



**Conclusions**

In patients undergoing uLMS-PCI, there were significant temporal changes in baseline demographics with increasing patient age and comorbid burden observed over time. Additionally, uLMS-PCI procedural complexity increased over time, with the number of vessels treated, LMS-PCI involving the LAD and circumflex, number of stents used, use of intravascular imaging and rotational atherectomy all increasing significantly through the study period. Despite increases in patient and procedural complexity, the adjusted annual rates of peri-procedural MI, in-hospital MACCE, and acute procedural complication declined significantly over time.These data help inform procedural planning, patient choice and consent, and Heart Team discussions.

**Conflicts of interest:** None.

**Financial Support:** None

**Supplemental Materials:**

Supplemental Methods   
Supplemental Tables S1-S3

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**Table 1:** Baseline characteristics of patients undergoing uLMS-PCI by procedure year in the United Kingdom 2009-2017

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **2009**  **(n=1089)** | **2010**  **(n=1091)** | **2011**  **(n=1259)** | **2012**  **(n=1453)** | **2013**  **(n=1474)** | **2014**  **(n=1625)** | **2015**  **(n=1757)** | **2016**  **(n=2122)** | **2017**  **(n=2652)** | **p-value** |
| Age (years), ±SD | 70.7±12.2 | 71.3±12.1 | 71.3±11.5 | 72.3±11.6 | 71.8±11.6 | 71.6±12.0 | 71.6±11.8 | 71.7±11.6 | 71.6±11.9 | 0.002 |
| Female sex, no. (%) | 361 (33.1) | 350 (32.1) | 373 (29.7) | 459 (31.6) | 428 (29.1) | 451 (27.8) | 502 (28.6) | 622 (29.3) | 780 (29.4) | 0.006 |
| Body Mass Index, ±SD | 27.6±5.7 | 28.0±5.6 | 28.5±5.6 | 28.0±5.6 | 27.9±5.6 | 28.0±5.5 | 28.0±5.5 | 28.0±5.3 | 28.1±5.7 | 0.685 |
| Hypertension, no. (%) | 701 (64.7) | 722 (66.5) | 818 (65.6) | 1,007 (70.0) | 963 (66.8) | 1,088 (67.8) | 1,107 (66.2) | 1,412 (67.1) | 1,724 (67.3) | 0.389 |
| Diabetes mellitus, no. (%) | 237 (22.0) | 224 (21.0) | 293 (23.8) | 330 (23.4) | 376 (25.9) | 446 (27.7) | 451 (26.0) | 583 (27.9) | 737 (28.4) | <0.001 |
| Previous MI, no. (%) | 339 (35.5) | 368 (37.2) | 461 (39.1) | 515 (37.8) | 531 (36.8) | 592 (37.2) | 618 (35.9) | 707 (34.0) | 901 (34.7) | 0.008 |
| Previous CVA/PVD, no. (%) | 179 (16.5) | 176 (16.2) | 240 (19.2) | 258 (17.9) | 233 (16.2) | 242 (15.1) | 254 (15.2) | 290 (13.8) | 418 (16.3) | 0.134 |
| Chronic kidney disease, no. (%) | 63 (5.9) | 78 (7.3) | 68 (5.5) | 108 (7.9) | 94 (6.6) | 108 (6.8) | 126 (7.3) | 104 (5.0) | 131 (5.1) | 0.019 |
| Valvular heart disease, no. (%) | 32 (2.9) | 42 (3.9) | 44 (3.5) | 60 (4.2) | 67 (4.6) | 69 (4.3) | 84 (5.0) | 130 (6.2) | 181 (7.1) | <0.001 |
| Potent DAPT, no. (%) | 0 (0) | 7 (0.6) | 20 (1.6) | 73 (5.0) | 192 (13.1) | 309 (19.2) | 400 (22.8) | 575 (27.1) | 796 (30.1) | <0.001 |
| Previous PCI, no. (%) | 274 (25.2) | 288 (26.6) | 355 (28.4) | 369 (25.6) | 460 (31.2) | 505 (31.3) | 572 (32.9) | 693 (32.9) | 842 (32.2) | 0.003 |
| ACS presentation, no. (%) | 544 (49.9) | 604 (55.3) | 681 (54.1) | 773 (53.2) | 792 (53.7) | 897 (55.2) | 1,001 (57.0) | 1,147 (54.1) | 1,444 (54.5) | <0.001 |
| Ejection fraction (%), ±SD | 48.0 (11.6) | 47.7 (11.8) | 47.3 (12.2) | 46.6 (12.5) | 46.5 (12.8) | 47.2 (12.1) | 47.2 (12.4) | 46.8 (12.7) | 47.8 (11.9) | 0.271 |
| Ejection fraction <30%, no. (%) | 70 (9.6) | 70 (9.9) | 97 (11.1) | 129 (13.2) | 139 (13.2) | 111 (10.2) | 133 (11.8) | 166 (12.1) | 18.3 (10.8) | 0.530 |
| No. of diseased vessels ±SD | 1.86±0.95 | 1.99±0.97 | 1.99±1.00 | 2.07±0.98 | 2.05±0.98 | 2.06±0.97 | 2.08±0.98 | 2.05±0.96 | 2.12±1.00 | <0.001 |

DAPT – Dual antiplatelet therapy; MI – myocardial infarction; CVA – cerebrovascular disease; PVD – peripheral vascular disease; ACS – acute coronary syndrome

**Table 2:** Procedural variables of patients undergoing uLMS-PCI by procedure year in the United Kingdom 2009-2017

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **2009**  **(n=1090)** | **2010**  **(n=1091)** | **2011**  **(n=1259)** | **2012**  **(n=1453)** | **2013**  **(n=1474)** | **2014**  **(n=1625)** | **2015**  **(n=1757)** | **2016**  **(n=2122)** | **2017**  **(n=2652)** | **p-value trend** |
| No. of vessels attempted, ±SD | 1.99±0.79 | 2.02±0.80 | 2.04±0.80 | 2.08±0.81 | 2.11±0.79 | 2.08±0.78 | 2.13±0.79 | 2.11±0.79 | 2.17±0.79 | <0.001 |
| Bifurcation intervention, no. (%) | 251 (23.0) | 252 (23.1) | 292 (23.2) | 359 (24.7) | 403 (27.3) | 412 (25.3) | 480 (27.3) | 564 (26.6) | 754 (28.4) | <0.001 |
| CTO attempted, no. (%) | 60 (6.0) | 55 (5.3) | 63 (5.3) | 69 (5.0) | 88 (6.2) | 79 (5.0) | 102 (6.0) | 93 (4.6) | 141 (5.6) | 0.715 |
| Restenosis, no. (%) | 101 (9.9) | 68 (6.3) | 88 (7.2) | 90 (6.3) | 117 (8.2) | 115 (7.3) | 108 (6.3) | 161 (7.9) | 218 (8.7) | 0.253 |
| No. of stents used, ±SD | 2.06±1.45 | 2.11±1.39 | 2.15±1.42 | 2.20±1.44 | 2.21±1.52 | 2.16±1.42 | 2.20±1.38 | 2.18±1.39 | 2.30±1.40 | <0.001 |
| 1 stent used, no. (%) | 369 (34.2) | 373 (34.5) | 425 (34.0) | 468 (32.5) | 464 (31.8) | 517 (32.1) | 552 (31.7) | 641 (30.5) | 750 (28.4) | <0.001 |
| 2+ stents used, no. (%). | 710 (65.8) | 701 (65.5) | 825 (66.0) | 972 (67.5) | 996 (68.2) | 1,093 (67.9) | 1,188 (68.3) | 1,466 (69.5) | 1,890 (71.6) | <0.001 |
| GPI used, no. (%) | 239 (24.1) | 225 (21.9) | 204 (17.5) | 209 (15.0) | 163 (11.8) | 152 (9.9) | 138 (8.2) | 125 (6.3) | 152 (6.3) | <0.001 |
| Intravascular imaging used, no. (%) | 417 (40.4) | 467 (44.6) | 573 (47.6) | 654 (46.5) | 698 (49.5) | 786 (48.3) | 920 (52.8) | 1,088 (54.7) | 1,403 (58.6) | <0.001 |
| Rotational atherectomy, no. (%) | 81 (8.1) | 75 (7.3) | 115 (9.8) | 151 (11.0) | 170 (12.1) | 203 (12.8) | 184 (10.8) | 261 (12.7) | 310 (14.4) | <0.001 |
| Laser, no. (%) | 2 (0.2) | 7 (0.7) | 7 (0.6) | 5 (0.3) | 10 (0.7) | 7 (0.4) | 4 (0.2) | 6 (0.3) | 4 (0.2) | 0.823 |
| Cutting balloon, no. (%) | 58 (5.8) | 62 (6.1) | 67 (5.7) | 75 (5.5) | 107 (7.7) | 105 (6.6) | 112 (6.6) | 173 (8.4) | 180 (8.3) | <0.001 |
| Microcatheter, no. (%) | 1 (0.1) | 6 (0.6) | 19 (1.6) | 36 (2.6) | 51 (3.7) | 63 (4.0) | 109 (6.4) | 133 (6.5) | 173 (8.0) | <0.001 |
| Mechanical LV support use, no. (%) | 58 (5.7) | 50 (4.8) | 57 (4.7) | 66 (4.7) | 54 (3.8) | 49 (3.1) | 53 (3.1) | 36 (1.8) | 56 (2.2) | <0.001 |
| Femoral access, no. (%) | 691 (64.2) | 623 (58.1) | 699 (56.4) | 667 (46.3) | 654 (44.9) | 625 (38.8) | 560 (32.2) | 559 (26.8) | 629 (24.1) | <.0001 |
| Dual access, no. (%) | 78 (7.2) | 61 (5.7) | 85 (6.9) | 115 (8.0) | 67 (7.5) | 102 (6.3) | 137 (7.9) | 151 (7.2) | 226 (8.7) | 0.0216 |

CTO – chronic total occlusion; GPI – glycoprotein inhibitor; LV – left ventricular

**Table 3:** Crude unadjusted outcomes after uLMS-PCI by procedure year in the United Kingdom 2009-2017

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **2009**  **(n=1090)** | **2010**  **(n=1091)** | **2011**  **(n=1259)** | **2012**  **(n=1453)** | **2013**  **(n=1474)** | **2014**  **(n=1625)** | **2015**  **(n=1757)** | **2016**  **(n=2122)** | **2017**  **(n=2652)** | **p-value trend** |
| **Acute procedural outcomes** | | | | | | | | | | |
| No. successful lesions, ±SD | 2.03±1.16 | 1.94±1.04 | 1.98±1.06 | 2.00±1.04 | 2.03±1.09 | 2.00±1.06 | 2.07±1.09 | 2.02±1.04 | 2.13±1.10 | <0.001 |
| Major side branch loss, no. (%) | 13 (1.4) | 9 (0.9) | 13 (1.1) | 19 (1.4) | 15 (1.1) | 18 (1.1) | 21 (1.2) | 18 (0.9) | 27 (1.0) | 0.469 |
| Coronary dissection, no. (%) | 59 (6.2) | 59 (6.1) | 75 (6.5) | 66 (4.9) | 71 (5.1) | 52 (3.3) | 71 (4.2) | 63 (3.1) | 81 (3.1) | <0.001 |
| Coronary perforation, no. (%) | 5 (0.5) | 14 (1.4) | 9 (0.8) | 15 (1.1) | 12 (0.9) | 8 (0.5) | 14 (0.8) | 20 (1.0) | 18 (0.7) | 0.469 |
| Slow flow, no. (%) | 5 (0.5) | 7 (0.7) | 11 (1.0) | 13 (1.0) | 14 (1.0) | 7 (0.5) | 10 (0.6) | 8 (0.4) | 10 (0.4) | 0.022 |
| Shock induction, no. (%) | 3 (0.3) | 7 (0.7) | 10 (0.9) | 8 (0.6) | 11 (0.8) | 11 (0.7) | 14 (0.8) | 11 (0.5) | 15 (0.6) | 0.948 |
| Any complication, no. (%) | 86 (9.0) | 83 (8.5) | 107 (9.3) | 107 (7.9) | 117 (8.5) | 83 (5.3) | 117 (6.9) | 111 (5.3) | 144 (5.4) | <0.001 |
| **Clinical Outcomes** | | | | | | | | | | |
| Peri-procedural MI, no. (%) | 34 (3.1) | 23 (2.1) | 15 (1.2) | 10 (0.6) | 18 (1.2) | 9 (0.6) | 11 (0.6) | 6 (0.3) | 9 (0.3) | <0.001 |
| Peri-procedural CVA, no. (%) | 1 (0.1) | 1 (0.1) | 1 (0.1) | 2 (0.1) | 1 (0.1) | 0 (0) | 0 (0) | 5 (0.2) | 5 (0.2) | 0.220 |
| Transfusion, no. (%) | 8 (0.7) | 8 (0.7) | 7 (0.6) | 9 (0.6) | 8 (0.5) | 10 (0.6) | 12 (0.7) | 11 (0.5) | 5 (0.2) | 0.036 |
| Access site complication, no. (%) | 21 (2.1) | 22 (2.1) | 23 (1.9) | 29 (2.0) | 27 (1.9) | 30 (1.9) | 51 (3.0) | 49 (2.4) | 25 (1.0) | 0.2631 |
| Emergency PCI/CABG, no. (%) | 2 (0.2) | 7 (0.6) | 8 (0.6) | 8 (0.6) | 4 (0.3) | 3 (0.2) | 10 (0.6) | 5 (0.2) | 7 (0.3) | 0.539 |
| Acute kidney injury, no. (%) | 5 (0.5) | 7 (0.6) | 5 (0.4) | 8 (0.6) | 4 (0.3) | 3 (0.2) | 5 (0.3) | 2 (0.1) | 2 (0.1) | <0.001 |
| In-patient mortality, no. (%) | 22 (2.0) | 20 (1.8) | 28 (2.2) | 28 (1.9) | 29 (2.0) | 34 (2.1) | 40 (2.2) | 40 (1.9) | 43 (1.7) | 0.510 |
| In-patient MACCE, no. (%) | 55 (5.0) | 33 (3.0) | 38 (3.0) | 38 (2.6) | 47 (3.2) | 43 (2.6) | 49 (2.8) | 48 (2.3) | 56 (2.1) | <0.001 |
| In-patient major bleed, no. (%) | 17 (2.0) | 18 (1.6) | 14 (1.1) | 25 (1.7) | 15 (1.0) | 24 (1.5) | 27 (1.5) | 25 (1.1) | 25 (0.9) | 0.095 |

MI – myocardial infarction; CVA – cerebrovascular accident; CABG – coronary artery bypass surgery; MACCE – major adverse cardiovascular events

**Figure Legends**

**Figure 1: Trends of uLMS-PCI in the United Kingdom 2009-2017.** Left Panel: Change in total numbers of PCI in the study population (STEMI, emergency non-STEMI and cardiogenic shock excluded) in light blue bars and unprotected LMS-PCI (uLMS-PCI) in dark over time; Right Panel: Percentage of total-PCI represented by uLMS-PCI over time.

**Figure 2: Acute procedural complications during uLMS-PCI in the United Kingdom 2009-2017.** Panels indicate serial changes in coronary dissection (p<0.001 for trend), shock induction by PCI (non-significant trend), occurrence of slow flow (p=0.02 for trend), loss of a major side branch (non-significant trend), and all acute coronary complications combined including coronary perforation, ventilation required and DC cardioversion required (p<0.001 for trend).

**Figure 3: Clinical outcomes following uLMS-PCI in the United Kingdom 2009-2017.** Panels indicate annual odds ratios indexed to 2009 for clinical outcomes including peri-procedural myocardial infarction (MI) (p<0.001 for trend), in-hospital death (non-significant trend), in-hospital major adverse cardiovascular events (MACCE) (p<0.001 for trend), in-hospital major bleeding (non-significant trend), and acute coronary complications (p<0.001 for trend).

**Figure 4: Associates of in-hospital MACCE.** Multi-variate adjusted model for in-hospital outcomes following LMS-PCI in the United Kingdom 2009-2017 (significant factors highlighted in red, non-significant highlighted in black). PVD – peripheral vascular disease; DAPT – dual anti-platelet therapy; CTO – chronic total occlusion.