# **Contributors to the growth of same day discharge after elective percutaneous coronary intervention: a regional analysis from the British Cardiovascular Intervention Society**

**Short running title:**  Same day discharge after elective PCI

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**Introduction**

Percutaneous coronary intervention (PCI) is the commonest revascularization modality for the treatment of coronary artery disease, with over 80,000 PCI procedures performed annually in the UK. Historically, the majority of PCI procedures undertaken for elective indications were admitted for overnight observation to detect and manage potential post-procedural complications, such as major bleeding, vascular access site complications, stent thrombosis and recurrent ischemic events 1.

However, advances in stent technology, procedural techniques (such as intravascular imaging), and pharmacotherapy, alongside changes in access site practice, have all contributed to a reduction in these early peri-procedural events 1-3. Hence, early complications following PCI are now relatively rare, indicating the feasibility of adopting same day discharge (SDD) practice in lower risk PCI cases. Correspondingly, financial pressures for reducing hospitalization costs, a need for improved bed utilization, and patient preference for shorter length of stay 4, also favor a transition to SDD practice in lower risk (elective) and uncomplicated PCI cases5, 6.

The safety of SDD has been demonstrated by a large number of randomized clinical trials4, 7-10, observational studies11-17 and meta-analyses18, 19 performed across different healthcare systems, with no significant increases in major adverse cardiovascular events, such as myocardial infarction (MI), stroke or cardiac death associated with SDD.

Whilst the safety of SDD has been evaluated in many studies, there is limited data around what patient and clinical factors have primarily driven the observed increases in SDD practice, and whether these factors differ in different regions within an individual healthcare system. For example, even in the UK, where SDD is the most common treatment model for elective PCI, there are marked regional differences (+ref 1st paper). Additionally, although advances in pharmacology, stent technology, and changes in access site practice towards transradial access favor transition towards SDD, their relative contribution to SDD after uncomplicated PCI in elective cases has not been evaluated in detail. Therefore, understanding the driving factors of changes in SDD practice would increase its utility (through an improved understanding of cases where SDD is/is not appropriate), and will help identify potential barriers for additional change in practice.

The aim of this study was to examine and compare the relative importance of patients’, procedural, regional and centre characteristics on SDD after uncomplicated elective PCI and how these have changed over time. We aimed to do this on a national and UK-regional level to gain insight into geographical differences on the factors that contributed to SDD.

**Methods**

*The BCIS database and analysis sample*

Data were collected by the British Cardiovascular Intervention Society (BCIS) and include over 99% of PCI procedures conducted in the National Health Service (NHS) in the United Kingdom from January 2007 to December 2014. The dataset contains around 120 variables covering demographic characteristics, clinical information, periprocedural and outcome variables, as previously described20.

We only included elective cases, for patients that had stable angina, were aged between 18 and 100 years old, and who underwent PCI at an NHS centre in England, Wales or Scotland. These cases are considered to be eligible for SDD, as more acute cases such as those undertaken following an acute coronary syndrome are unlikely to be SDD. Also, cases with missing outcome (SDD), age, sex or centre data were excluded. Centres with a low number of elective PCI procedures in a year (fewer than 100), were excluded for that particular year only to ensure that outliers did not drive our findings. Finally, we excluded cases with arterial and/or procedural complications, bleeding prior to discharge or adverse hospital outcomes –such as Q or non Q wave MI, emergency coronary artery bypass grafting (CABG) and death (Supplementary Table 1). Such cases were excluded because complicated cases would be admitted to overnight stay by default and would never be SDD cases. Duplicated cases were identified by the patient and hospital identifier, age, sex, date of the procedure and date of discharge.

*Statistical Analysis*

We considered the contribution of 27 variables on changes in SDD, each of which would be available at the time of one making a decision to SDD (Table 1). Of these variables, 23 included missing values after the exclusion criteria were applied. Missingness information is displayed in Supplementary Table 2. We used multiple imputation by chained equations to generate 10 imputed datasets, each of which was constructed over 10 iterations; convergence of the mean and the standard deviation was assessed for each imputed variable. Within this technique, missing values were replaced by values drawn from the posterior distribution, constructed for each incomplete variable using the other variables (including year information and the outcome) as predictors, plus random error.21, 22 We did not exclude variables with high levels of missingness since it has been shown that it is preferable for such variables to be included in the multiple imputation model.23 In the following analyses, estimates were pooled using Rubin’s rules.24

We quantified the contribution (or relative importance) of predictors of SDD over time using squared semi-partial correlations, a method introduced by Lindeman, Merenda and Gold.25 Within this analysis the contribution of each predictor to the R2 (obtained by linearly regressing the predictors over the outcome) represents its relative importance. To account for correlations between predictors and shared variance of the outcome, multiple models are fitted with all possible permutations of ordering for the predictors. Then, the additional contribution of each predictor to the R2 is averaged across all permutations. The value obtained is considered the relative importance of each predictor on the outcome and higher values indicate a larger contribution to SDD, without specifying direction. Bootstrapping techniques were used to obtain empirical 95% confidence intervals for the relative importance of each predictor and for the bivariate differences of the relative importance between predictors.

All analyses were performed using Stata MP version 15.1 and R version 3.5.126. The R package *relaimpo*27 using the input ‘*lmg’* was used for aspects of the second analysis.

**Results**

A total of 178,540 elective cases in England, Wales and Scotland that underwent PCI between 2007 and 2014 were included in the analysis. Figure 1 displays the inclusion criteria in detail. Overall, 42.5% of the cases were SDD and 57.5% were admitted for overnight stay. Over time, we observed substantial increases in SDD, from 23.3% in 2007 to 58.2% in 2014.

Table 1 displays temporal changes in patients’ and procedural characteristics separately for the SDD and overnight stay cases. Overnight stay cases were consistently older than SDD cases over time, and mean age in both groups increased. Females and Whites were less likely to be SDD, compared to males or non-Whites. Patients with important medical history (such as those with history of MI, CABG, PCI, stroke or peripheral vascular disease) were less likely to be SDD, although the risk profile of both cohorts increased over time. The prevalence of previous PCI and hypertension increased over time in both the SDD (from 25% to 37% and from 51% to 61%, respectively) and overnight stay cohorts (from 28% to 39% and from 55% to 64%, respectively) between 2007 and 2014, with smaller increases observed for previous MI, hypercholesterolemia, peripheral vascular disease, previous stroke, diabetes and renal disease. Previous CABG was the only medical history related variable whose prevalence decreased over time, from 13.2% to 11.2% for SDD and from 22.2% to 14.1% for overnight stay cases. Similarly, other characteristics indicating higher risk patients (i.e. moderate or poor LVEF, multivessel disease or attempted, left main territory attempted and implantation of drug eluting stents), were consistently less prevalent for the SDD compared to the overnight stay cohort, but increased over time in both groups. The use of GP IIIb/IIa inhibitors substantially decreased over time in both the SDD (from 6.3% to 1.8%) and the overnight stay (from 16.6% to 6.3%). Finally, we observed a marked change in access site practice from predominantly transfemoral PCI to transradial, while transradial PCI cases were more likely to be SDD compared to transfemoral cases. Transradial PCI increased from 26.2% in 2007 to 71.7% in 2014 in the SDD cohort and from 26.4% to 56.8% in the overnight stay cohort.

To address the relative importance of these characteristics on the change of SDD, we grouped them into eight clinically-meaningful classes (Table 2) and followed the aforementioned procedure structuring all the different permuted ordered sub-models of these classes. The values obtained represented the relative importance of each class instead of each predictor independently. These classes included: demographic characteristics, medical history, structural cardiac disease, pharmaceutics, procedural characteristics, access site, centre volume and region (Strategic Health Authority or SHA). To acknowledge which variables were most important within classes (when included a limited number of predictors, i.e. the pharmaceutics and the centre volume), we reran the same analysis excluding one predictor at each time and compared the results.

Within this analysis, the total variance of the outcome explained by the model over time ranged between 11.7% and 17.5% (Supplementary Table 3). SDD was mainly explained by regional rather than patients’ and procedural characteristics (Figure 2). The relative importance of Strategic Health Authorities (SHA), the now superseded high-level NHS organizations, was higher than the cumulative of all other classes, and statistically significantly so, in every year (Supplementary Figure 1). Nevertheless, a small reduction over time was observed in the relative importance of SHAs, from 49.2% (95%CI 45.4 – 52.4%) in 2007 to 43.4% (95%CI 39.9 – 46.6%) in 2014, reaching a maximum of 56.2% (95%CI 52.7 – 58.7%) in 2010 (Supplementary Table 3). Centre volume characteristics had the next highest relative importance, increasing from 8.95% (95%CI 7.0 – 10.9%) in 2007 to 19.8% (95%CI 16.7 – 22.4%) in 2014, which was equally attributed to the prevalence and the size of elective cases within centres. Among the patients’ and procedural characteristics, pharmaceutics and access site had the highest relative importance values. We noticed a decrease for the pharmaceutics group, from 14.3% (95%CI 12.1 – 16.4%) to 7.1% (95%CI 5.5 – 8.8%), which was almost entirely attributed to decreasing uses of glycoprotein IIb/ IIIa inhibitors over time, and an increase for access site over time, from 3.6% (95%CI 2.3 – 5.1%) to 11.8% (95%CI 9.4 – 14.3%). From 2010 onwards, the relative importance of access site for the adoption of SDD was statistically significantly greater that the relative importance of all other characteristics, apart from SHA (Supplementary Figure 1).

Figure 3 displays the relative importance of the aforementioned factors on SDD change over time and over regions. The relative importance of different groups of factors varied across the different regions. In some regions centre volume was the dominant contributor to SDD change, such as in the South West and the East of England, though in other regions, SDD was driven by multiple factors, for example in the North East and the South East Coast. Access site seems to have been the most important contributor in Wales and the second most important, after centre volume, in London. Furthermore, we found that the medical history of the patients was also an important contributor in some regions (i.e. in the South Central, Yorkshire and the Humper, and Wales), whereas its contribution to the overall SDD change was of minor importance (Figure 2). Finally, the contribution of pharmaceutics was relevant mainly in the East and West Midlands until 2010 and deteriorated afterwards.

**Discussion**

This paper aimed to provide insight into the factors that have driven the temporal changes observed in SDD after uncomplicated elective PCI in a national cohort of patients, where SDD has become the predominant practice. The main findings from this paper can be summarised as follows: (i) regional characteristics were the most important determinant to SSD change over time, followed by centre characteristics and access site practice, (ii) the main drivers for the temporal changes in SDD varied markedly across different regions.

Our group has previously reported that SDD has become the predominant model of elective PCI in the UK and that the observed 30-day mortality rates for the SDD cases were lower than the expected ones derived from the BCIS risk model.28 While such findings can be, in part, attributed to the high pressure for reducing hospitalisation costs and for better bed utilisation, this analysis unpicks patient- and centre-level factors that have contributed to the observed temporal changes in SDD practice. By taking advantage of the high SDD use in our sample (e.g. more than half of the uncomplicated elective cases in 2014), we were able to quantify the factors that have driven operator and institutional practices towards SDD. To the best of our knowledge no other study has examined the drivers of SDD at either national or regional level within a healthcare system where SDD has grown to predominant practice after uncomplicated elective PCI.

Advances in pharmacology, stent technology and changes in access site practice and procedural techniques have contributed to reduce the rates of early or late complications, in patients undergoing PCI. Within the same period that our sample was collected, studies have been published showing that most early complications following PCI occur within the first 6 hours or after 24 hours of the procedure,14, 29 suggesting that in hospital overnight observation would have not significantly change the capture of these later complications. In the STRIDE study of Jabara et al. adverse in hospital outcomes, such as death or access site complications, occurred in 5.3% of the patients, with none of them occurring between 6 and 24 hours of the procedure. In another analysis from Small et al. no complications occurred within the same period of time (6-14 hrs) in 1174 patients who were admitted to overnight observation -17% of which were elective cases. At that time, many studies examined the safety and feasibility of SDD in lower risk elective cases that underwent uncomplicated PCI, showing that SDD was neither inferior nor superior to overnight stay in terms of early or late complications, including death, MI, revascularisation, bleeding and vascular complications7, 8, 12, 16, 30.

Whilst many studies have revealed the safety of SDD in carefully selected lower risk patients that underwent uncomplicated PCI and its cost effectiveness, there are healthcare systems that are slower in its adoption. A study by Rao et al. with data collected by the CathPCI Registry from 2004 to 2008, included 107018 elderly elective cases of which 97% underwent successful PCI and 1.25% were day discharged.11 A more recent study including all the PCI procedures from 2009 to 2013 in Florida and New York showed that SDD practice across all PCI procedures increased from 2.5% to 7.4% and within the elective outpatient sample (including the elective patients that remained at the hospital for a day or less) SDD was applied to 31%. 31 Finally, Amin et al. used data of 279,987 PCI procedures from 2009 to 2012, 9% of which were performed transradially. Even though in-hospital complications, i.e. bleeding, transfusion and vascular complications, appeared to 2.8% of the cases, only 5.3% where day excluded.32

In our current analysis within this period, we report that changes in SDD practice has been mainly driven by regional factors, rather than patient or procedural factors. Indeed, individual cardiologists make the decision whether to keep a patient under overnight observation or to SDD, but these decisions are likely based on centre-level practice, rather than standardised guidelines, thereby leading to the observed regional disparities. It is only very recently where consensus documents have been published that have highlighted the type of patients where SDD should be considered33, and neither European or UK guidelines have provided any guidance around SDD.

We have observed that centre volume, which represents both the volume and the prevalence of elective cases within centres, was an important contributor to SDD practice change, mostly from 2011 onwards. However, individual factors’ importance varied considerably between different regions and centre volume was observed to have been the leading driver in some regions (e.g. in South West and the East of England), but not across all regions. Access site was found to be the main contributor of SDD in Wales, while in other regions (such as in North East and the South East Coast) no particular factor was observed to have been the core contributor. One could interpret these findings to imply that adoption of SDD in uncomplicated elective cases is driven by different factors in different regions, reflecting differences in local service structures and with different institutional and health economic challenges, rather than through differences in case mix. Other important drivers of SDD that are not captured by the BCIS dataset which may vary between regions, such as patients’ preference, distance of residency, the presence of support networks at home and the time of the PCI procedure may contribute to the observed differences in the relative contribution of the various drivers of SDD that we describe .

Even though advances in transfemoral PCI, such as use of vascular closure devices, ultrasound guided access and a move towards smaller sheath sizes have encouraged early ambulation, adoption of transradial PCI has become the mainstay access route in the UK, accounting for 84% of all PCI procedures undertaken in 201734. This contrasts to other healthcare systems where transfemoral PCI was the default access site. For example, outcomes report from the NCDR featured 37% of transradial PCI in 2017.33 This change is attributed to evidence of reduced in-hospital complications, i.e. major bleeding and vascular complications35, 36 and subsequently reduction in mortality events in high-risk patients. In the current analysis, we report that radial access site contribution to SDD was increased over time, although it differed considerably between different regions. Access site appeared to be the main contributor in Wales and at the time was of minor importance in other regions, such as in East Midlands and the South East Coast.

Between 2007 and 2010, pharmaceutics, in particular the decline in national GP IIb/IIIa inhibitor use in elective PCI, was the second most important factor in explaining the growth of SDD practice. Prior studies have reported that GP IIb/IIIa inhibitor use was negatively associated with SDD17 perhaps related to concerns around major bleeding complications or the need to given drug infusions for at least 12 hours post procedure necessitating overnight stay. Finally, we observed that medical history was also an important contributor in some regions, such as the South Central and the Wales, although its overall contribution was low compared to the rest of the factors studied. This finding enhances the significant variation of the factors’ contribution between regions, as medical history was of minor importance in other regions, for example in South West and the East of England.

This study has several limitations, both within its statistical analysis and the data used. First, we lack information on the time of the procedure (cases which underwent PCI in late noon or afternoon would not be discharged later at night), the observation period after the procedure, the operators reason for overnight stay/SDD, the patients’ preference and eligibility (e.g. social support, near in distance residency, etc). Intuitively, such data could be of high importance in explaining overall SDD change or the heterogeneity between regions, but we are unable to summarise this quantitatively. Secondly, due to lack of a gold-standard statistical method for calculating the relative importance of predictors on a binary outcome, we structured linear regression models and relied our results on the decomposition of the R2 obtained (i.e. the proportion of the outcome variance explained the model). Fitting a linear model to a binary outcome might result to probability predictions of the outcome out the (0,1) range, which subsequently might affect the R2. Thirdly, the R2 values calculated are low (meaning the models explain a low proportion of the total variation). However, it is quite reasonable that the true variation of SDD in uncomplicated elective cases is mostly at random, as these are of lower risk cases and safety of SDD has been widely documented, and inclusion of the abovementioned information might not offer much additional contribution to the R2. Finally, it has been shown that radial lounges within centres have also contributed much to the increase of SDD37, 38, data which also were absent in our sample.

In conclusion, we could suggest that there is ample scope for increasing SDD practice further, especially within SHAs that have low SDD rates. To achieve this and to create more homogeneity and cost-saving through SDD, a decision-making consensus (e.g. standardised guidelines) on SDD for carefully selected patients who underwent peri- and post-uncomplicated PCI is essential. Moreover, we believe that this analysis adds significant information to the current literature and could be used by healthcare systems that are slower in the adoption of SDD.

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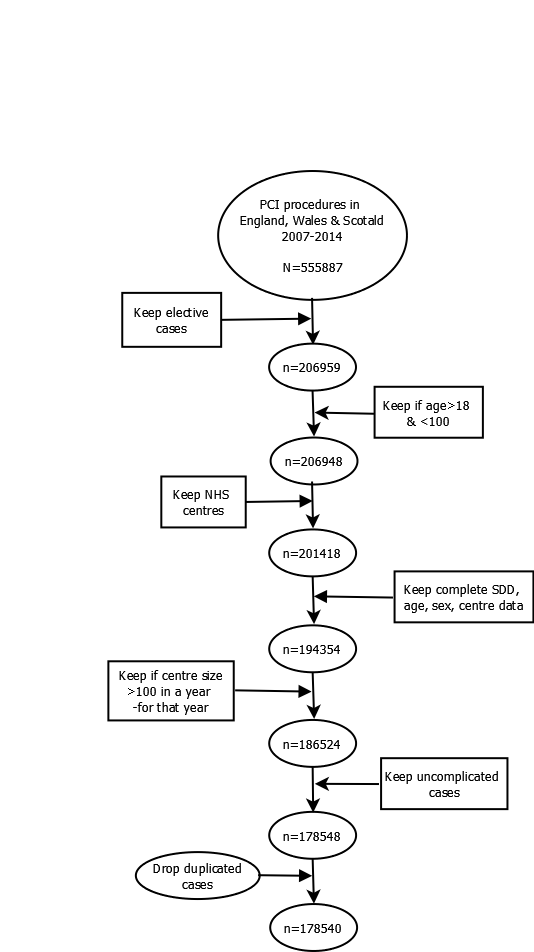
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*Figure 1: Flowchart of sample selection*



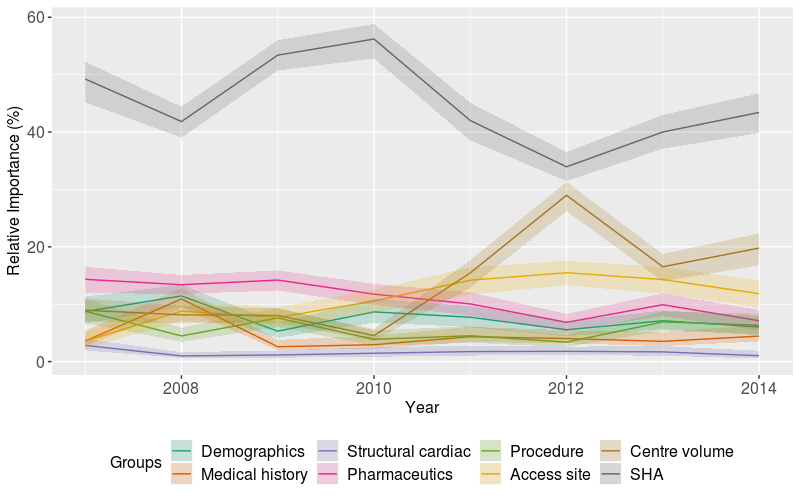
*Table 1: Temporal change in patients’ and procedural characteristics for the same day discharge and the uncomplicated overnight stay cases*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | | **2007** | | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** |
| **Sum of cases**  *No (%)* | **SDD** | | | 4996 | | 8482 | 9475 | 9061 | 10532 | 11799 | 12677 | 8791 |
|  |  | | | (0.23) | | (0.34) | (0.4) | (0.39) | (0.45) | (0.5) | (0.55) | (0.58) |
|  | **uncON** | | | 16787 | | 14340 | 13986 | 12901 | 11586 | 10414 | 10414 | 6305 |
|  |  | | | (0.77) | | (0.66) | (0.6) | (0.61) | (0.55) | (0.5) | (0.45) | (0.42) |
| **Centre elective prevalence**  *Median (IQR)* | **SDD** | | | 0.47 | | 0.47 | 0.41 | 0.36 | 0.36 | 0.34 | 0.33 | 0.33 |
|  |  | | | (0.41-0.55) | | (0.41-0.61) | (0.35-0.49) | (0.33-0.43) | (0.32-0.41) | (0.31-0.41) | (0.28-0.39) | (0.28-0.39) |
|  | **uncON** | | | 0.46 | | 0.43 | 0.38 | 0.35 | 0.35 | 0.34 | 0.32 | 0.33 |
|  |  | | | (0.41-0.51) | | (0.37-0.56) | (0.34-0.50) | (0.32-0.45) | (0.30-0.41) | (0.29-0.38) | (0.28-0.37) | (0.28-0.37) |
| *Mean (Sd)* |  | | |  | |  |  |  |  |  |  |  |
| **Centre elective size** | **SDD** | | | 780 | | 714.3 | 578.9 | 503.6 | 522.2 | 506 | 463.2 | 416 |
|  |  | | | (428.4) | | (358.1) | (259.7) | (229.8) | (261.4) | (261.8) | (231.5) | (202.2) |
|  | **uncON** | | | 722.2 | | 654.4 | 562.8 | 510.8 | 463 | 398.6 | 399 | 345.7 |
|  |  | | | (418.9) | | (356.4) | (298.8) | (277.7) | (242.0) | (209.6) | (203.5) | (193.1) |
| **Age** | **SDD** | | | 63.3 | | 63.9 | 64 | 64.2 | 64.6 | 64.9 | 64.8 | 65.2 |
|  |  | | | (10.1) | | (10.2) | (10.3) | (10.4) | (10.5) | (10.5) | (10.6) | (10.6) |
|  | **uncON** | | | 64.6 | | 64.9 | 65.5 | 65.7 | 65.9 | 66.4 | 66.5 | 67.2 |
|  |  | | | (10.3) | | (10.5) | (10.6) | (10.7) | (10.8) | (10.8) | (11.0) | (10.8) |
| **BMI** | **SDD** | | | 29 | | 28.8 | 29 | 29.2 | 28.9 | 29.1 | 29 | 29 |
|  |  | | | (4.7) | | (4.9) | (4.9) | (5.0) | (4.9) | (5.1) | (5.0) | (5.0) |
|  | **uncON** | | | 28.6 | | 28.8 | 28.7 | 28.8 | 28.9 | 28.9 | 28.9 | 29 |
|  |  | | | (5.0) | | (4.9) | (5.1) | (4.9) | (5.1) | (5.0) | (5.3) | (5.1) |
| *% of non-missing records* | | |  | |  |  |  |  |  |  |  |  |
| **Gender** |  | | |  | |  |  |  |  |  |  |  |
| Male | **SDD** | | | 76.6 | | 76.3 | 75.8 | 76 | 77.4 | 77 | 76.7 | 77.5 |
|  | **uncON** | | | 74.1 | | 73.9 | 75.1 | 74.6 | 74.6 | 75.3 | 75.3 | 75.9 |
| Female | **SDD** | | | 23.4 | | 23.7 | 24.2 | 24 | 22.6 | 23 | 23.3 | 22.5 |
|  | **uncON** | | | 25.9 | | 26.1 | 24.9 | 25.4 | 25.4 | 24.7 | 24.7 | 24.1 |
| **Ethnicity** |  | | |  | |  |  |  |  |  |  |  |
| Caucasian | **SDD** | | | 82 | | 70 | 84.6 | 83.4 | 82.7 | 84.2 | 82.8 | 84.2 |
|  | **uncON** | | | 83.4 | | 88.8 | 88.8 | 84.9 | 82.4 | 83.2 | 83.2 | 84.7 |
| Black | **SDD** | | | 0.7 | | 0.8 | 0.7 | 0.8 | 0.9 | 0.7 | 0.9 | 0.5 |
|  | **uncON** | | | 0.5 | | 0.5 | 0.7 | 0.7 | 0.8 | 0.9 | 0.9 | 0.6 |
| Asian | **SDD** | | | 6.6 | | 6.1 | 6.1 | 7.7 | 7.4 | 6 | 6.3 | 6 |
|  | **uncON** | | | 6.1 | | 5.8 | 6.4 | 8.2 | 8.1 | 7.3 | 7.3 | 6.4 |
| Other | **SDD** | | | 10.7 | | 23 | 8.5 | 8 | 9 | 9 | 10 | 9.2 |
|  | **uncON** | | | 10 | | 4.9 | 4.1 | 6.1 | 8.7 | 8.6 | 8.6 | 8.3 |
| **Medical history** | | |  | |  |  |  |  |  |  |  |  |
| Previous MI | **SDD** | | | 30.9 | | 31.8 | 33.2 | 31.5 | 31.5 | 31.9 | 31.8 | 32.4 |
|  | **uncON** | | | 34.8 | | 35.2 | 35.5 | 35.3 | 34.6 | 36 | 36 | 35.2 |
| Previous CABG | **SDD** | | | 13.2 | | 10.8 | 11.1 | 11.4 | 10.5 | 11 | 10.9 | 11.2 |
|  | **uncON** | | | 22.2 | | 14.9 | 14.6 | 14.7 | 15.5 | 15.2 | 15.2 | 14.1 |
| Previous PCI | **SDD** | | | 25.5 | | 26.9 | 31.4 | 32.3 | 33.4 | 34.5 | 36.3 | 37.1 |
|  | **uncON** | | | 28 | | 31.4 | 32.9 | 35.1 | 36.2 | 38.8 | 38.8 | 38.9 |
| High Cholesterol | **SDD** | | | 57.5 | | 52.3 | 67.8 | 65.1 | 62.8 | 63.1 | 63.9 | 61.2 |
|  | **uncON** | | | 61.3 | | 67.2 | 66.5 | 64.5 | 64.1 | 64.3 | 64.3 | 61.2 |
| Hypertension | **SDD** | | | 51.2 | | 48 | 59.3 | 61 | 60.3 | 59.9 | 62.2 | 61.5 |
|  | **uncON** | | | 55.5 | | 60.8 | 62 | 61.9 | 63.4 | 64.1 | 64.1 | 63.8 |
| Peripheral vascular disease | **SDD** | | | 2.9 | | 2.9 | 4.2 | 4.9 | 4.4 | 4.2 | 4.4 | 3.6 |
|  | **uncON** | | | 5.4 | | 5.7 | 6.1 | 5.9 | 6 | 6.1 | 6.1 | 6.4 |
| Previous Stroke | **SDD** | | | 2.1 | | 2.8 | 3.8 | 3.4 | 3.2 | 3.4 | 3.4 | 2.8 |
|  | **uncON** | | | 3.5 | | 3.9 | 3.8 | 3.9 | 4.1 | 4.4 | 4.4 | 4.2 |
| Diabetes | **SDD** | | | 18.6 | | 19.2 | 20.7 | 20.6 | 22.2 | 22.6 | 23.7 | 22.4 |
|  | **uncON** | | | 20.8 | | 21.9 | 22.1 | 22.8 | 23.5 | 24.9 | 24.9 | 24.6 |
| **Renal history** | | |  | |  |  |  |  |  |  |  |  |
| No renal disease | **SDD** | | | 99 | | 98.7 | 98.6 | 98.2 | 98.8 | 98.6 | 98.4 | 98.4 |
|  | **uncON** | | | 97.8 | | 97.5 | 97.3 | 97.6 | 96.7 | 96.9 | 96.9 | 96.8 |
| High creatinine  (>200 μmol/l – no dialysis) | **SDD** | | | 0.6 | | 0.7 | 1 | 1.2 | 0.7 | 0.8 | 0.8 | 0.9 |
|  | **uncON** | | | 1.6 | | 1.6 | 1.9 | 1.6 | 2.2 | 1.7 | 1.7 | 1.9 |
| Dialysis | **SDD** | | | 0.3 | | 0.6 | 0.4 | 0.6 | 0.5 | 0.5 | 0.7 | 0.7 |
|  | **uncON** | | | 0.6 | | 0.9 | 0.8 | 0.8 | 1 | 1.4 | 1.4 | 1.3 |
| **Smoking** |  | | |  | |  |  |  |  |  |  |  |
| Ex smoker | **SDD** | | | 50.7 | | 50 | 49.3 | 48.8 | 45.9 | 43.7 | 45.2 | 46 |
|  | **uncON** | | | 49 | | 49.6 | 48.3 | 47.4 | 47 | 47.1 | 47.1 | 46.6 |
| Current smoker | **SDD** | | | 12.7 | | 14.2 | 14.1 | 13.4 | 13.5 | 12.8 | 12.9 | 11.9 |
|  | **uncON** | | | 12.2 | | 12.8 | 12.3 | 11.9 | 12.1 | 11.4 | 11.4 | 10.2 |
| Never smoked | **SDD** | | | 36.6 | | 35.8 | 36.6 | 37.8 | 40.6 | 43.6 | 41.8 | 42.2 |
|  | **uncON** | | | 38.8 | | 37.6 | 39.4 | 40.7 | 40.9 | 41.5 | 41.5 | 43.1 |
| **LVEF** |  | | |  | |  |  |  |  |  |  |  |
| Good | **SDD** | | | 82.6 | | 79.7 | 80.3 | 82.6 | 83 | 84.2 | 83 | 83.8 |
|  | **uncON** | | | 78.8 | | 77.8 | 78.3 | 79 | 78.7 | 79 | 79 | 81.3 |
| Moderate  (LVEF 30-50%) | **SDD** | | | 14.1 | | 15.8 | 15.6 | 15 | 14.9 | 12.9 | 14.3 | 13.2 |
|  | **uncON** | | | 15.7 | | 17.3 | 18.1 | 17.1 | 17.6 | 16.7 | 16.7 | 14.8 |
| Poor  (LVEF <30%) | **SDD** | | | 3.2 | | 4.5 | 4.1 | 2.4 | 2.1 | 2.9 | 2.8 | 3 |
|  | **uncON** | | | **5.5** | | 4.9 | 3.6 | 3.9 | 3.7 | 4.3 | 4.3 | 3.9 |
| **Multi-vessel disease** | **SDD** | | | 20 | | 21.8 | 23.7 | 26.2 | 26.1 | 26.4 | 24.9 | 25.2 |
|  | **uncON** | | | 26.3 | | 27.8 | 29 | 28.1 | 30.1 | 28.1 | 28.1 | 28.8 |
| **Valvular heart disease** | **SDD** | | | 0.8 | | 0.7 | 1 | 1.3 | 1.2 | 1.8 | 1.7 | 1.9 |
|  | **uncON** | | | 1 | | 1.3 | 1.7 | 2 | 2.7 | 2.7 | 2.7 | 3 |
| **Pharmaceutics** | |  | |  | |  |  |  |  |  |  |  |
| Warfarin | **SDD** | | | 1.2 | | 1.0 | 1.1 | 1.0 | 0.9 | 1.5 | 1.7 | 2.1 |
|  | **uncON** | | | 1.2 | | 1.3 | 1.3 | 1.3 | 1.7 | 2.3 | 2.3 | 2.3 |
| GP IIa/IIIb inhibitor | **SDD** | | | 6.3 | | 4.9 | 3.2 | 2.9 | 2.7 | 2.7 | 2 | 1.8 |
|  | **uncON** | | | 16.6 | | 13.1 | 9.8 | 7.8 | 7.8 | 6.8 | 6.8 | 6.3 |
| **CTO vessels attempted** | **SDD** | | | 12.4 | | 11.4 | 11.5 | 12.3 | 11.7 | 12.9 | 11.5 | 10.8 |
|  | **uncON** | | | 13.3 | | 15.6 | 14.9 | 14.8 | 15.7 | 15.5 | 15.5 | 17 |
| **Stent type** |  | | |  | |  |  |  |  |  |  |  |
| No stents used | **SDD** | | | 11.1 | | 11.4 | 12.1 | 10 | 9.5 | 8.1 | 8.7 | 8 |
|  | **uncON** | | | 7.6 | | 7.9 | 8 | 8.9 | 8.4 | 8.4 | 8.4 | 8.5 |
| BMS only | **SDD** | | | 32.4 | | 27.4 | 21.7 | 17.9 | 13.8 | 10.3 | 6.3 | 3.5 |
|  | **uncON** | | | 24.4 | | 18.8 | 15.4 | 12.2 | 9.7 | 5.9 | 5.9 | 3.7 |
| DES only | **SDD** | | | 51.3 | | 56 | 62.6 | 68.3 | 74 | 79.1 | 83.1 | 87.3 |
|  | **uncON** | | | 62.2 | | 68.8 | 73 | 76 | 79.3 | 82.9 | 82.9 | 86.4 |
| Both | **SDD** | | | 5.2 | | 5.2 | 3.7 | 3.9 | 2.8 | 2.4 | 2 | 1.2 |
|  | **uncON** | | | 5.8 | | 4.5 | 3.6 | 3 | 2.6 | 2.8 | 2.8 | 1.4 |
| **Left Main stem attempted** | **SDD** | | | 2.5 | | 2.3 | 2.8 | 2.4 | 2.6 | 3 | 3.5 | 3.8 |
|  | **uncON** | | | 3.1 | | 3.8 | 3.9 | 4.8 | 5.6 | 7.6 | 7.6 | 7.1 |
| **Multi-vessel attempted** | **SDD** | | | 12.9 | | 15 | 16.4 | 16.4 | 15.8 | 15.8 | 14.7 | 15.6 |
|  | **uncON** | | | 17.2 | | 16.9 | 16.4 | 17.3 | 17.6 | 16.6 | 16.6 | 17.2 |
| **Access site** |  | | |  | |  |  |  |  |  |  |  |
| Femoral | **SDD** | | | 73.2 | | 61.7 | 54.7 | 46.1 | 39 | 30.7 | 26.5 | 25.2 |
|  | **uncON** | | | 72.5 | | 66 | 59.1 | 54 | 48.6 | 40.6 | 40.6 | 37.6 |
| Radial | **SDD** | | | 26.2 | | 37.3 | 43.9 | 51.9 | 58.3 | 66.3 | 70.2 | 71.7 |
|  | **uncON** | | | 26.4 | | 32.3 | 38.3 | 43 | 47.7 | 54.6 | 54.6 | 56.8 |
| Multiple | **SDD** | | | 0.5 | | 0.7 | 1.1 | 1.8 | 2.3 | 2.7 | 2.9 | 2.7 |
|  | **uncON** | | | 0.8 | | 1.3 | 2.1 | 2.6 | 3.3 | 4.3 | 4.3 | 5.4 |
| Other | **SDD** | | | 0.1 | | 0.2 | 0.3 | 0.2 | 0.4 | 0.3 | 0.3 | 0.3 |
|  | **uncON** | | | 0.2 | | 0.4 | 0.5 | 0.4 | 0.3 | 0.4 | 0.4 | 0.2 |

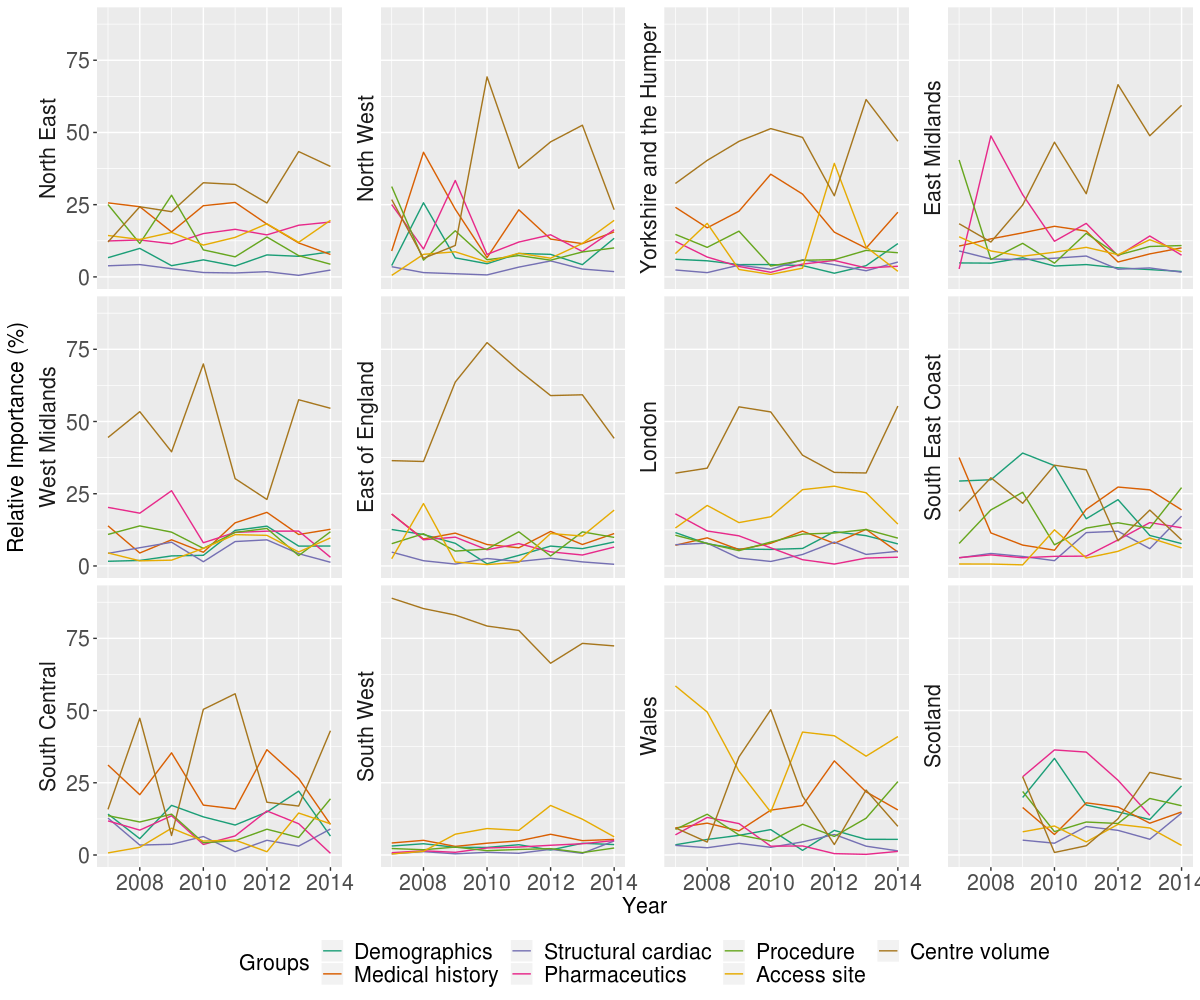
*Table 2: Variables grouped into classes*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Demographic** | **Medical history** | **Structural Cardiac** | **Pharmaceutics** | **Procedure** | **Access site** | **Centre volume** | **Region** |
| Age | Previous MI | Left Ventricular Ejection Fraction | Warfarin | CTO vessels attempted | Access site (Femoral/Radial/ Multiple/Other) | Centre elective prevalence | SHA |
| Sex | Previous CABG | Multivessel Disease | Glycoprotein IIa/IIIb inhibitor | Stent type |  | Centre elective size |  |
| Ethnicity | Previous PCI | Valvular Heart Disease |  | Left Main Stem attempted |  |  |  |
|  | High Cholesterol |  |  | Multivessel attempted |  |  |  |
|  | Hypertension |  |  |  |  |  |  |
|  | Peripheral Vascular Disease |  |  |  |  |  |  |
|  | Previous Stroke |  |  |  |  |  |  |
|  | Diabetes |  |  |  |  |  |  |
|  | Renal History |  |  |  |  |  |  |
|  | Smoking |  |  |  |  |  |  |
|  | BMI |  |  |  |  |  |  |

*Figure 2: Relative importance (%) of groups with 95% CI shaded*



*Figure 3: Regionally relative importance (%) of groups*



Results are not available for Scotland in 2007-8 due to limited cases

***Supplementary Table 1: Detailed procedural and arterial complications and adverse hospital outcome***

|  |  |  |
| --- | --- | --- |
| **Adverse hospital outcome** | **Procedural complications** | **Arterial complications** |
| Q wave MI (stable angina and NSTEMI patients only) | Aortic dissection | False aneurysm - conservative management |
| Non Q wave MI (stable angina patients only) | Coronary perforation | False aneurysm - compression |
| Emergency CABG | Heart block requiring pacing | False aneurysm - thrombin injection |
| Arterial complication | DC cardioversion | False aneurysm - surgical management |
| Death | No flow/slow flow phenomenon | Haemorrhage - no haematoma |
| CVA – Embolic | Ventilated | Haemorrhage - delayed discharge |
| CVA – Bleed | Shock induced by procedure | Haemorrhage - surgery required |
| TIA / RIND |  | Haemorrhage - retroperitoneal |
| Re-intervention PCI |  | Arterial occlusion |
| Blood Transfusion |  | Arterial dissection |
| Renal failure/dialysis |  | Any other surgical intervention |
| GI bleed |  |  |
| Tamponade |  |  |
| Platelet Transfusion |  |  |

CABG=Coronary Artery Bypass Graft; CVA=Cerebrovascular accident; DC=Direct Current; GI=Gastrointestinal; MI=Myocardial infarction; NSTEMI=Non-ST-elevation myocardial infraction; PCI=Percutaneous Coronary Intervention; RIND=Reversible Ischemic Neurologic Deficit; TIA=Transient Ischemic Attacks.

*Supplementary Table 2: Missing values frequency and relative frequency for the imputed variables*

|  |  |
| --- | --- |
| **Variable** | **Missing values, n**  **(%)** |
| Agea | 0 |
| Sexa | 0 |
| Ethnicity | 45660  (25.57) |
| Previous MI | 18342  (10.27) |
| Previous CAGB | 51071  (28.60) |
| Previous PCI | 6524  (3.65) |
| High Cholesterol | 6297  (3.53) |
| Hypertension | 6297  (3.53) |
| Peripheral Valvular Disease | 6297  (3.53) |
| Previous Stroke | 6297  (3.53) |
| Diabetes | 6582  (3.69) |
| Renal history | 1077  (0.60) |
| Smoking | 21171  (11.86) |
| BMI | 65920  (36.92) |
| LVEF | 75170  (42.10) |
| Multivessel Disease | 16478  (9.23) |
| Valvular Heart Disease | 6297  (3.53) |
| Warfarin | 13623  (7.63) |
| GP IIb/IIIa inhibitor | 11598  (6.50) |
| CTO vessels attempted | 15631  (8.75) |
| Stents type | 8665  (4.85) |
| Left Main Stem attempted | 3913  (2.19) |
| Multivessel attempted | 3913  (2.19) |
| Access site | 4840  (2.71) |
| Centre elective sizea | 0 |
| Centre elective prevalencea | 0 |
| SHA | 0 |
| Year | 0 |

BMI=Body Mass Index; BMS=Bare mare stent; CABG=Coronary Artery Bypass Graft; CTO=Chronic Total Occlusion; DES=Drug-eluting stent; GP=Glycoprotein; LVEF=Left ventricular ejection fraction; MI=Myocardial infarction; PCI=Percutaneous Coronary Intervention; SHA=Strategic Health Authorities

aIncomplete cases on these variables were excluded from the analysis

*Supplementary Table 3: Relative importance (%) of groups with 95% CI*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Total R2 (%)** | **Demographics** | **Medical history** | **Structural cardiac disease** | **Pharmaceutics** | **Procedure** | **Access site** | **Centre volume** | **SHA** |
| **2007** | 11.73 | 8.74  [6.60 – 11.17] | 3.58  [2.76 – 5.39] | 2.81  [1.87 – 4.13] | 14.34  [12.10 – 16.40] | 8.76  [6.79 – 11.02] | 3.58  [2.28 – 5.14] | 8.95  [6.99 – 10.93] | 49.24  [45.42 – 52.45] |
| **2008** | 15.84 | 11.45  [9.61 – 13.46] | 10.92  [9.45 – 12.72] | 0.99  [0.65 – 1.62] | 13.40  [11.65 – 15.07] | 4.47  [3.34 – 5.77] | 8.80  [7.14 – 10.64] | 8.15  [6.77 – 9.77] | 41.83  [38.98 – 44.35] |
| **2009** | 15.6 | 5.31  [4.03 – 6.70] | 2.58  [2.02 – 3.88] | 1.15  [0.67 – 1.88] | 14.20  [12.30 – 15.94] | 7.59  [6.08 – 9.35] | 7.69  [5.98 – 9.47] | 8.05  [6.77 – 9.30] | 53.42  [50.62 – 55.78] |
| **2010** | 12.9 | 8.66  [6.80 – 10.73] | 2.95  [2.30 – 4.58] | 1.46  [0.88 – 2.43] | 11.75  [9.78 – 13.53] | 3.89  [2.78 – 5.42] | 10.56  [8.45 – 12.61] | 4.54  [3.54 – 5.56] | 56.21  [52.73 – 58.72] |
| **2011** | 11.83 | 7.73  [5.99 – 9.69] | 4.33  [3.44 – 6.18] | 1.74  [1.05 – 2.86] | 10.05  [8.01 – 11.80] | 4.50  [3.28 – 6.14] | 14.19  [11.78 – 16.73] | 15.45  [12.97 – 17.96] | 42.01  [38.73 – 45.20] |
| **2012** | 16.55 | 5.55  [4.41 – 6.98] | 4.02  [3.27 – 5.42] | 1.79  [1.15 – 2.75] | 6.84  [5.36 – 8.31] | 3.39  [2.54 – 4.66] | 15.49  [13.37 – 17.76] | 28.98  [25.98 – 31.39] | 33.94  [31.46 – 36.67] |
| **2013** | 13.83 | 7.12  [5.69 – 8.72] | 3.53  [2.82 – 5.10] | 1.69  [1.05 – 2.73] | 9.91  [8.01 – 11.75] | 6.91  [5.47 – 8.79] | 14.30  [11.96 – 16.51] | 16.53  [14.16 – 18.77] | 40.01  [36.93 – 42.75] |
| **2014** | 17.45 | 6.05  [4.68 – 7.69] | 4.44  [3.45 – 6.42] | 1.03  [0.54 – 1.96] | 7.11  [5.51 – 8.85] | 6.34  [4.80 – 8.32] | 11.83  [9.43 – 14.34] | 19.78  [16.70 – 22.45] | 43.42  [39.93 – 46.60] |

SHA=Strategic Health Authorities

*Supplementary Figure 1: Difference in Relative importance (%) between groups (row – column variable) with 95% CI shaded*



Overlap of the difference line (black) on the red dashed line dhows no statistical difference of the relative importance of the two groups at that particular time point