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Original Investigation

Prognosis of patients with chronic and hospital-acquired anaemia after acute coronary syndromes

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ABBREVIATIONS

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3 ACS = acute coronary syndrome

4 CA = chronic anaemia

5 CI = confidence interval

6 GRACE score = Global Registry of Acute Coronary Events

7 HAA = hospital-acquired anaemia

8 HR = hazard ratio

9 LVEF = left ventricular ejection fraction

10 MACE = major adverse cardiovascular events

11 MI = myocardial infarction

12 PCI = percutaneous coronary intervention

13 PPI = proton pump inhibitor

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ABSTRACT

Discharge anaemia is common following acute coronary syndromes (ACS). However, it is unknown if chronic anaemia (CA) and hospital-acquired anaemia (HAA) are associated with similar outcomes.

In this retrospective analysis of 4083 ACS admissions treated with percutaneous coronary intervention in Switzerland (SPUM-ACS registry), 1896 patients (46.4%) had discharge anaemia (CA: n=643[15.7%] vs. HAA: n=1253[30.7%]). Landmark analysis that matched patients with CA (n=504) and HAA (n=866) with non-anaemic patients found increased one-year major adverse cardiovascular events (cardiovascular mortality, myocardial infarction, stroke) among patients with CA (6.9% vs. 3.0%, HR 2.073, 95% CI 1.039- 4.134, p=0.039) and HAA (3.8% vs. 2.3%, HR 1.772, 95% CI 1.002-3.232, p=0.049). Only CA was associated with increased one-year all-cause mortality (7.9% vs. 1.6%, HR 4.255, 95% CI 1.950-9.284, p<0.001).

CA and HAA were associated with poor one-year cardiovascular outcomes. Only CA was associated with increased all-cause mortality suggesting that HAA and CA represent distinct subclinical entities.

Keywords

Acute coronary syndrome, invasive coronary angiography, anaemia

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INTRODUCTION

Baseline anaemia is prevalent among patients presenting with acute coronary syndromes (ACS) and is strongly associated with increased mortality [1,2]. It is typically a chronic anaemia associated with older age and comorbidities such as diabetes mellitus, chronic heart failure, chronic kidney disease and cerebrovascular disease [1]. However, patients can also develop hospital-acquired anaemia (HAA) during admission with ACS through bleeding that complicates pharmacological and invasive therapies, as well as through haemodilution [3]. It has been shown to develop in over 50% of ACS patients and is associated with increased mortality [4–6] .

There is limited data available on the cardiovascular outcomes of patients with discharge anaemia following ACS. Furthermore, CA and HAA likely represent distinct pathophysiological groups, and it is unknown if these groups experience similar outcomes following ACS.

We aimed to determine the relationship between discharge anaemia (CA and HAA) and one-year clinical outcomes among patients with ACS treated with percutaneous intervention (PCI). We performed a retrospective analysis of patients admitted with ACS to four university hospitals in Switzerland and compared the one-year outcomes of patients discharged with CA and HAA with those of patients discharged without anaemia.

METHODS

Patients

Data was obtained from the SPUM-ACS (Special Program University Medicine - Acute Coronary Syndromes) registry, a cohort of consecutive patients admitted with ACS to four university hospitals in Switzerland. All patients were aged 18 years or over. The only exclusion criteria were: severe physical disability, inability to comprehend the study or life expectancy of less than 1 year (for non-cardiac reasons). Further details of this registry have been reported previously [7]. For the present study, patients hospitalised between 2009 and 2017 who received PCI were selected. The World Health Organisation thresholds were used to define anaemia as a haemoglobin <130 g/l in men and <120 g/l in women. Patients were defined as having CA if they were anaemic on both admission and discharge. Patients without anaemia on admission who were discharged with anaemia were defined as having HAA.

Primary and secondary endpoints

To eliminate the direct impact of bleeding on the endpoints, a landmark analysis was performed with a starting point of 7 days post-angiography. Events before this timepoint were not counted. The primary endpoint was defined as one-year major adverse cardiovascular events (MACE), a composite of cardiovascular mortality, recurrent MI (using the universal definition of MI) and stroke. The secondary endpoint was defined as one-year all-cause mortality. The incidence of events during follow-up was ascertained by telephone consultation 30 days post discharge, and in a clinical face-to-face visit at one year. When patients could not be reached for the one-year follow-up visit, medical information was obtained from primary care physicians, family members, hospital records or a registry office. Three certified cardiologists adjudicated all events.

Statistical analysis

Normally distributed, continuous variables are expressed as mean \pm SD and compared using the 2-tailed Student *t*-test. Non-normally distributed continuous variables are expressed as a median with interquartile range and analysed using the Mann-Whitney *U* test. Comparisons between categorical variables were performed using the Pearson χ^2 test. Missing values in baseline clinical characteristics were treated with multiple imputation in order to create five imputed datasets. Baseline and treatment characteristics as well as clinical endpoint rates are

1 presented for a single imputed dataset. Logistic and Cox regression analyses were performed on each imputed
2 dataset before pooling of estimates as per Rubin's Rules [8]. Multiple logistic regression was used to identify
3 independent factors associated with HAA and CA. These models included the following covariates: age, sex,
4 hypertension, diabetes, previous cardiovascular disease, valvular disease, chronic lung disease, active or previous
5 malignancy, previous gastrointestinal bleeding, smoking status, body mass index (BMI), baseline use of
6 anticoagulation/P2Y₁₂ agent, heart rate, systolic blood pressure, ECG ischaemia, Killip class, type of ACS,
7 stenting vs. balloon angioplasty only, presence of thrombus, P2Y₁₂ agent prescribed. A 1:1 propensity score-
8 matched analysis with a nearest-neighbour matching algorithm was used to manage intergroup differences in
9 baseline and treatment variables prior to the sampling of the discharge haemoglobin level. Univariate Cox
10 proportional hazards models and Kaplan-Meier analysis evaluated the impact of discharge anaemia on the clinical
11 endpoints. Cubic spline functions were derived from multivariate Cox models of the unmatched populations and
12 were plotted with four degrees of freedom. Among patients with a CRP value at the time of admission, a subgroup
13 analysis was performed. A p-value <0.05 was defined as statistically significant. Statistical analysis was
14 performed using R version 3.5.1.

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RESULTS

Study population

Among 4,083 patients, anaemia was present in 643 (16.0%) on admission and 1896 (46.4%) at discharge. Among those with discharge anaemia, 1253 patients (66.1%) had HAA compared with 643 patients (33.9%) with CA (**Table 1**). Only 9 patients with baseline anaemia were discharged with a normal haemoglobin value.

Baseline clinical characteristics

Missing values in baseline clinical characteristics were managed with multiple imputation (**Online Table 1**). The median discharge haemoglobin level was 139 g/l (IQR 133.00-146.00) in the non-anaemic (NA) group compared with 118.00 g/l (IQR 108.00-124.00) in the HAA group and 107.00 g/l (IQR 92.00-116.00) in the CA group (**Table 2**). Although all three groups (NA, CA, HAA) experienced a decrease in median haemoglobin level between admission and discharge, this was largest among HAA patients (NA: 9.00 g/l vs. HAA: 22.00 g/l vs. CA: 8.00 g/l, $p < 0.001$). Both HAA and CA groups differed significantly from the NA group for the majority of baseline factors (**Table 1**). Compared with the NA group, patients with discharge anaemia (HAA and CA) were significantly older, more often female, and had a higher prevalence of the majority of comorbidities including hypertension, diabetes mellitus, previous cardiovascular disease, valvular disease, chronic lung disease, previous/active malignancy, and previous gastrointestinal bleeding. With regards to clinical features, **they also had** higher GRACE scores, lower left ventricular ejection fractions (LVEF) and lower estimated glomerular filtration rates (eGFR). Conversely, the discharge anaemia groups had a significantly lower body mass index (BMI) and lower rates of smoking.

Treatment factors

In the unmatched population, the NA and discharge anaemia groups differed significantly with regards to a number of treatment factors (Table 2). In general, patients with discharge anaemia were more likely to have three or more stents implanted, TIMI grade flow < 3 following PCI and be prescribed clopidogrel over prasugrel or ticagrelor. Although there was a high degree of compliance with ACS prescription guidelines, both discharge anaemia groups had fewer patients prescribed a statin. There was a higher rate of proton pump inhibitor (PPI) prescriptions in the discharge anaemia groups, and this was highest in the CA group. The HAA group had the highest occurrence of coronary thrombosis identified during angiography, with the CA group having the lowest.

1 The CA group also had a significantly lower proportion of patients with a percentage coronary stenosis of $\geq 95\%$
2 at the site of the culprit lesion.

3

4 **Factors associated with the CA and HAA**

5 Multiple logistic regression applied to the unmatched population demonstrated that diabetes, chronic lung disease,
6 chronic kidney disease, history of malignancy, and history of gastrointestinal bleeding were independently
7 associated with CA. Additionally, low BMI and baseline use of oral anticoagulation and clopidogrel were
8 independently correlated with CA. A history of malignancy was the only comorbidity independently associated
9 with the development of HAA. However, HAA was also associated with baseline use of oral anticoagulation,
10 raised GRACE score, elevated heart rate on admission, and the presence of thrombus during coronary
11 angiography.

12

13 **Propensity-score matched analyses**

14 *Chronic anaemia*

15 After 1:1 propensity score matching, 504 patients without discharge anaemia and 504 patients with CA were
16 deemed equivalent in terms of all baseline and treatment factors, with the exception of baseline haemoglobin
17 levels which were 147.00 g/l and 119.00 g/l, respectively ($p < 0.001$) (**Table 1 + 2**). The median discharge
18 haemoglobin level was 137 g/l in the NA group and 109 g/l in the CA group ($p < 0.001$). Patients in the NA and
19 CA groups experienced a similar decrease in haemoglobin level between admission and discharge (NA: 8.00 g/l
20 (IQR 3.00-15.00) vs. CA 8.00 g/l (IQR 3.00-15.00), $p = 0.949$). Baseline haemoglobin demonstrated a positive
21 correlation with baseline eGFR in the CA group but not in the NA group (**Online Figure 1**).

22

23 At one-year, the primary endpoint (MACE) occurred in 3.0% of patients in the NA group and 6.9% of patients in
24 the CA group (HR 2.073, 95% CI 1.039- 4.134, $p = 0.039$) (**Figure 1**). The CA group was also noted to have
25 markedly higher rates of the secondary endpoint (all-cause mortality) compared with the NA group (7.9% vs.
26 1.6%, HR 4.255, 95% CI 1.950-9.284, $p < 0.001$). These findings were corroborated with Kaplan-Meier analyses
27 (**Figure 2A**).

28

29 Cubic spline functions demonstrated an exposure-response relationship, with rates of MACE and all-cause
30 mortality increasing significantly with decreases in haemoglobin level below 120 g/l (**Figure 3A**).

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2 *Hospital-acquired anaemia*

3 After 1:1 propensity score matching, 866 patients with HAA and 866 patients without discharge anaemia
4 presented no significant differences in baseline or treatment factors (**Table 1 + 2**). The median baseline
5 haemoglobin value was 143.00 g/l in the NA group and 142.00 g/l in the HAA group (p=0.088). The median
6 discharge haemoglobin value was 135 g/l in the NA group and 119 g/l in the HAA group (p<0.001). This
7 corresponded to a median decrease in haemoglobin level between admission and discharge of 7.00 g/l (IQR 2.00-
8 12.00) in the NA group compared with 23.00 g/l (IQR 15.00-34.00) in the HAA group (p<0.001).

9

10 At one-year, the primary endpoint occurred in 2.3% of patients in the NA group compared with 3.8% of patients
11 in the HAA group (HR 1.772, 95% CI 1.002-3.232, p=0.049) (**Figure 1**). With regards to the secondary endpoint,
12 similar rates were noted in the NA and HAA groups (1.3% vs. 1.8%, HR 1.452, 95% CI 0.647-3.628, p=0.363).
13 These findings were confirmed with Kaplan-Meier analyses (**Figure 2B**).

14

15 Cubic spline functions suggested an exposure-response relationship between discharge haemoglobin and MACE,
16 with rates of MACE increasing with decreases in haemoglobin below 120 g/l (**Figure 3B**). However, there was
17 no clear association between discharge haemoglobin and all-cause mortality.

18

19 **Medication compliance at one-year**

20 At one-year, compliance with ACS prescription guidelines was similar among surviving NA and discharge
21 anaemia patients, including similar rates of aspirin and P2Y₁₂ agent use (**Online Table 2**).

22

23 **C-reactive protein (CRP) in CA and HAA**

24 In a separate analysis, CRP values on admission were available for 1208 patients from the unmatched population.
25 After propensity score matching, median CRP was slightly higher in the HAA group (NA: 2.10 mg/l (IQR 0.90-
26 5.50) vs. HAA: 2.80 mg/l (IQR 1.10-6.93), p=0.021) and even higher in the CA group (NA: 2.10 mg/l (IQR 0.93-
27 6.62) vs. CA: 3.80 mg/l (IQR 1.30-16.80), p=0.004).

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DISCUSSION

The key findings of this retrospective analysis were:

- 1) Discharge anaemia among ACS patients treated with PCI was common (46.4%).
- 2) Both CA and HAA were independently associated with poorer one-year cardiovascular outcomes.
- 3) Only CA was associated with increased one-year all-cause mortality.

CA vs. HAA: different entities?

Our results demonstrate that patients with CA are a vulnerable group with more comorbidities and significantly worse outcomes following ACS. They also suggest that patients who develop HAA represent a distinct subclinical group with a different risk profile.

CA is often considered a marker of increasing age or the accumulation of comorbidities. However, this matched analysis demonstrates that CA is independently associated with significantly worse outcomes following ACS. A number of pathophysiological processes are responsible for the development of CA. Among patients ≥ 65 years old in the National Health and Nutrition Examination Survey (NHANES) III cohort, anaemia was explained by nutrient deficiency in one third, anaemia of chronic disease or chronic renal disease in another third, with the remaining third having unexplained anaemia [9]. CRP levels were also significantly higher among patients with anaemia of chronic disease. In the present study, CRP levels too were found to be significantly higher among patients with CA. Additionally, baseline haemoglobin correlated positively with baseline eGFR among CA patients. One could therefore postulate that anaemia of chronic disease and chronic renal disease may in part underlie the anaemia in the CA group.

Two important mechanisms that lead to the development of HAA are bleeding and haemodilution [3]. Bleeding can arise from antiplatelet and anti-thrombotic treatments prescribed following ACS, as well as from the catheterisation site used for PCI. Combined with a pre-existing bleeding tendency from underlying medical conditions or medications these patients may be at a particularly high risk of bleeding, leading to anaemia. In this study, the identification of malignancy and baseline oral anticoagulation as independent factors associated with the development of HAA provide support for this hypothesis. Additionally, the higher incidence of coronary thrombus in patients that went on to develop HAA may indicate that these were patients who were more likely to

1 have received adjunctive glycoprotein IIB/IIIa inhibitors, thus increasing their bleeding tendency further [10].
2 With regards to PPI usage, prescription rates at discharge in this study were similar to those in previously reported
3 studies [11,12]. There was a higher rate of PPI prescriptions at discharge among patients who developed HAA,
4 which could suggest a higher rate of gastrointestinal bleeding events in this group. Unfortunately, data on bleeding
5 events was not available for analysis. Therefore, we can only speculate about the contribution of bleeding events
6 to the development of HAA in this study. Interestingly, Salisbury *et al.* reported that in a cohort of ACS patients,
7 of which over 70% underwent PCI, only 13.5% of those who developed HAA had any reported bleeding,
8 emphasising that causes other than bleeding need to be considered in the development of HAA [6]. With regards
9 to gastrointestinal bleeding, the latest guidance from the European Society of Cardiology now recommend the
10 routine use of a PPI in combination with dual antiplatelet therapy [13]. Thus, it is likely that an increasing rate of
11 PPI prescriptions in the future could reduce the contribution of gastrointestinal bleeding to the development of
12 both HAA and CA [13].

13

14 Another important mechanism to consider is haemodilution, which can arise through the administration of IV
15 fluids/medications during hospitalisation, as well as through fluid retention in acute heart failure following ACS
16 [14,15]. While bleeding and haemodilution are likely to contribute to the development of HAA, further studies
17 are needed to elucidate the exact mechanisms behind HAA following ACS.

18

19 **Why is anaemia associated with poor outcomes?**

20 Patients with anaemia are known to receive fewer evidence-based treatments following ACS [16]. This could, in
21 part, explain their worse outcomes. However, in this analysis there were no significant differences in prescriptions
22 between anaemic and non-anaemic, both at time of discharge and at one-year follow-up. This suggested that
23 differences in pharmacological therapy did not explain the worse outcomes in discharge anaemia patients in this
24 study,

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26 One mechanism that may drive poorer outcomes among anaemic patients is a worsening of the imbalance between
27 myocardial oxygen supply and demand that is seen in coronary artery disease. This can be exacerbated by systemic
28 vasodilatation and increased sympathetic tone seen in anaemic patients which in turn drive increased stroke
29 volume and heart rate [17]. In the long-term, these haemodynamic changes can drive adverse myocardial
30 remodelling [18,19]. In addition, two non-haemodynamic mechanisms may include impaired vascular healing and

1 chronic inflammation among anaemic patients. Anaemic patients have been shown to have reduced circulating
2 endothelial progenitor cells following an ACS which could impair vascular healing [20]. Another consideration
3 is anaemia of chronic inflammation, a chronic inflammatory condition driven by an underlying inflammatory
4 disease [9]. Anaemia of chronic inflammation is independently associated with increased rates of hospitalisation
5 and mortality [9,21]. In the setting of ischaemic heart disease, inflammation is known to play an important role in
6 all stages of atherothrombosis [22]. Furthermore, CRP has been shown to be an potent predictor of future vascular
7 events, even when it lies in the high-normal range [23]. The present study noted raised CRP levels among the CA
8 group, suggesting anaemia of chronic disease may have been present in at least some of these patients.

10 **Why do HAA and CA have different outcomes?**

11 One possible explanation is that patients with HAA were only affected by the haemodynamic changes associated
12 with anaemia, whereas CA patients were also susceptible to non-haemodynamic complications such as chronic
13 inflammation. Another consideration is the duration of anaemia following discharge. Patients with CA were more
14 likely to have persistent anaemia during the follow-up period. Conversely, HAA may have resolved in some
15 patients during follow-up as these patients were more likely to have normal haematopoietic function. Interestingly,
16 Hasin *et al.* reported that among ACS patients discharged with anaemia, the outcomes of patients with resolving
17 anaemia were similar to those without discharge anaemia [5]. Thus, it is plausible that the better outcomes in this
18 group relate to recovery of haemoglobin levels in some of these patients.

20 **Time for intervention studies?**

21 There is sufficient evidence of the prognostic importance of anaemia following ACS to justify intervention
22 studies. These could explore the impact of standardised testing of haematinics in all ACS patients with baseline
23 anaemia in order to diagnose and treat deficiencies during the index admission. They could also evaluate the
24 benefits of a lower blood transfusion threshold, particularly in the context of HAA.

26 **Limitations**

27 This study is limited by its retrospective, observational design and thus these findings can only be considered as
28 hypothesis generating. However, the SPUM-ACS registry represents a multicentre cohort of consecutive patients
29 hospitalised with ACS. Given the very few exclusion criteria, we feel that the risk of bias is limited and that
30 patients included in this study are likely representative of those encountered in routine clinical practice. The

1 prevalence of anaemia in this cohort was similar to previously reported figures, further suggesting that this
2 population was representative [4]. Another limitation was the absence of data on bleeding events, blood
3 transfusions and administration of IV fluids, all of which would have given better context to the discharge
4 haemoglobin values. To tackle the absence of bleeding data, we performed a landmark analysis from day 7 post-
5 angiography in order to exclude events directly attributable to severe angiography-related bleeding rather than the
6 longer-term effects of anaemia. Finally, there was no data available on haemoglobin levels following discharge,
7 or whether patients received blood transfusions or other treatments for anaemia, thus it was not possible to evaluate
8 the outcomes of patients who possibly had resolution of anaemia during the follow-up period.

9

10 **Conclusions**

11 In an observational cohort of patients treated with PCI for ACS, both HAA and CA were associated with poorer
12 one-year cardiovascular outcomes. However, CA and HAA likely represent distinct subclinical entities as only
13 CA was associated with all-cause mortality.

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9 well as preparation, review, or approval of the manuscript.

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DISCLOSURES

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3 None.

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HUMAN SUBJECTS/INFORMED CONSENT STATEMENT

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This project did not require approval by an ethics committee. Data collection for SPUM-ACS study was

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approved by Swiss ethics (Swiss Ethics Committees on research involving humans) involving the ethics

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committees of each local centre (Lausanne, Geneva, Bern and Zurich) and complies with all laws and

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international ethics guidelines outlined in the Declaration of Helsinki. All human patients provided written,

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informed consent.

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ANIMAL STUDIES

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3 No animal studies were carried out by the authors of this study.

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FIGURE LEGENDS

4 **Figure 1: Forest plot of one-year endpoints in patients without discharge anaemia compared with patients**
5 **with: (A) chronic anaemia, and (B) hospital-acquired anaemia.** For each propensity-matched analysis, event
6 rates for each one-year clinical endpoint are presented for the non-anaemic and discharge anaemia groups along
7 with the hazard ratio and p-value from the corresponding Cox proportional hazards model. MACE represents a
8 composite of cardiovascular mortality, recurrent MI and stroke. CI = confidence interval; GRACE = Global
9 Registry of Acute Coronary Events; MACE = major adverse cardiovascular events; MI = myocardial infarction.

- 1 **Figure 2: Kaplan-Meier plots for propensity-score matched analyses of: (A) chronic anaemia, and (B)**
- 2 **hospital-acquired anaemia.** Landmark timepoint from which events were recorded was set at 7 days post-
- 3 angiography (dotted line). For each endpoint, the p-value from the corresponding log-rank test is presented.
- 4 MACE = major adverse cardiovascular events

- 1 **Figure 3: Cubic spline functions demonstrating the impact of discharge haemoglobin value on one-year**
- 2 **clinical endpoints for: (A) chronic anaemia, and (B) hospital-acquired anaemia. MACE = major adverse**
- 3 **cardiovascular events**

- 1 **Online Figure 1: Association between baseline eGFR and baseline haemoglobin among patients with**
- 2 **chronic anaemia.** eGFR = estimated glomerular filtration rate.

1 **TABLES**

2
3 **Table 1: Baseline characteristics of unmatched and matched population.** The unmatched population is
4 stratified by type of discharge anaemia. For the matched analysis, patients with hospital-acquired anaemia (HAA)
5 and chronic anaemia (CA) were matched to patients without discharge anaemia. Propensity-score matching (1:1)
6 used a nearest-neighbour algorithm and a caliper setting of 0.1.

BASELINE CHARACTERISTICS	UNMATCHED				MATCHED*					
	ALL DISCHARGE ANAEMIA				HOSPITAL-ACQUIRED ANAEMIA			CHRONIC ANAEMIA		
	No discharge anaemia (n=2178)	HAA (n=1253)	CA (n=643)	p-value	No discharge anaemia (n=866)	HAA (n=866)	p-value	No discharge anaemia (n=504)	CA (n=504)	p-value
Age, median (IQR)	59.20 [51.60, 68.50]	65.50 [56.30, 74.60]	72.00 [61.85, 79.70]	<0.001	62.85 [54.62, 72.28]	63.25 [54.90, 71.15]	0.888	68.45 [58.50, 76.43]	68.65 [59.63, 77.80]	0.330
Female (%)	346 (15.9)	341 (27.2)	158 (24.6)	<0.001	193 (22.3)	192 (22.2)	1.000	111 (22.0)	119 (23.6)	0.599
Hypertension (%)	1058 (48.6)	715 (57.1)	450 (70.0)	<0.001	455 (52.5)	466 (53.8)	0.630	327 (64.9)	333 (66.1)	0.740
Diabetes (%)	288 (13.2)	213 (17.0)	181 (28.1)	<0.001	144 (16.6)	127 (14.7)	0.290	115 (22.8)	120 (23.8)	0.766
Hypercholesterolemia (%)	1387 (63.7)	794 (63.4)	375 (58.3)	0.041	543 (62.7)	553 (63.9)	0.654	298 (59.1)	298 (59.1)	1.000
Previous MI (%)	226 (10.4)	134 (10.7)	136 (21.2)	<0.001	95 (11.0)	89 (10.3)	0.697	89 (17.7)	87 (17.3)	0.934
Previous PCI (%)	268 (12.3)	153 (12.2)	159 (24.7)	<0.001	108 (12.5)	99 (11.4)	0.553	113 (22.4)	102 (20.2)	0.442
Previous CABG (%)	55 (2.5)	41 (3.3)	54 (8.4)	<0.001	26 (3.0)	26 (3.0)	1.000	26 (5.2)	26 (5.2)	1.000
Previous stroke (%)	39 (1.8)	28 (2.2)	43 (6.7)	<0.001	20 (2.3)	17 (2.0)	0.740	22 (4.4)	17 (3.4)	0.514

Previous CVD (%)	388 (17.8)	265 (21.1)	249 (38.7)	<0.001	180 (20.8)	166 (19.2)	0.435	160 (31.7)	160 (31.7)	1.000
Valvular disease (%)	12 (0.6)	17 (1.4)	19 (3.0)	<0.001	4 (0.5)	8 (0.9)	0.385	7 (1.4)	9 (1.8)	0.801
Chronic lung disease (%)	56 (2.6)	39 (3.1)	46 (7.2)	<0.001	26 (3.0)	24 (2.8)	0.886	24 (4.8)	25 (5.0)	1.000
Previous/current malignancy (%)	122 (5.6)	100 (8.0)	92 (14.3)	<0.001	64 (7.4)	60 (6.9)	0.780	62 (12.3)	57 (11.3)	0.696
Previous GI bleed (%)	34 (1.6)	23 (1.8)	29 (4.5)	<0.001	17 (2.0)	16 (1.8)	1.000	16 (3.2)	17 (3.4)	1.000
Family history of CAD (%)	591 (27.1)	299 (23.9)	135 (21.0)	0.003	229 (26.4)	215 (24.8)	0.474	123 (24.4)	114 (22.6)	0.552
Smoking (%)	972 (44.6)	487 (38.9)	173 (26.9)	<0.001	344 (39.7)	351 (40.5)	0.769	159 (31.5)	160 (31.7)	1.000
BMI (kg/m ²)	27.59 (4.29)	26.34 (4.15)	26.31 (4.50)	<0.001	26.76 (3.91)	26.58 (4.19)	0.381	26.42 (3.92)	26.58 (4.49)	0.546
Baseline haemoglobin (g/l), median (IQR)	150.00 [142.00, 157.00]	139.00 [132.00, 146.00]	118.00 [109.00, 124.00]	<0.001	143.00 [136.00, 149.00]	142.00 [135.00, 149.00]	0.088	147.00 [140.00, 155.00]	119.00 [110.00, 125.00]	<0.001
Baseline haematocrit (%), median (IQR)	43.90 [41.70, 46.00]	41.00 [39.00, 43.00]	35.20 [32.90, 37.00]	<0.001	42.00 [40.00, 43.90]	41.70 [39.73, 43.80]	0.101	43.00 [41.00, 45.12]	35.50 [33.00, 37.00]	<0.001
eGFR, ml/min/1.73m ² , mean (SD)	92.62 (23.58)	85.70 (26.99)	78.16 (32.08)	<0.001	89.47 (23.33)	90.10 (26.11)	0.596	84.82 (22.83)	82.63 (31.50)	0.207
LVEF, mean (SD)	53.02 (10.33)	49.05 (11.73)	49.12 (12.65)	<0.001	50.80 (10.76)	50.97 (10.92)	0.751	50.47 (11.21)	50.42 (12.10)	0.943
ECG ischemia (%)	1790 (82.2)	1092 (87.2)	503 (78.2)	<0.001	742 (85.7)	737 (85.1)	0.786	390 (77.4)	398 (79.0)	0.594
Heart rate, beats-per-minute, mean (SD)	76.52 (18.65)	78.25 (17.06)	77.83 (17.47)	0.017	76.90 (15.82)	77.15 (16.46)	0.748	76.93 (16.79)	77.27 (17.69)	0.755
Systolic blood pressure, mmHg, mean (SD)	129.43 (23.17)	128.07 (25.74)	127.28 (24.40)	0.080	128.63 (22.89)	128.53 (25.10)	0.931	127.97 (22.61)	128.58 (24.77)	0.682
GRACE score, mean (SD)	130.54 (27.73)	148.82 (35.33)	155.22 (36.79)	<0.001	140.13 (27.99)	140.06 (30.56)	0.965	146.10 (31.53)	147.84 (32.32)	0.387

GRACE score >140 (%)	715 (33.8)	682 (56.1)	397 (64.1)	<0.001	397 (47.3)	388 (46.2)	0.679	266 (55.3)	281 (57.5)	0.539
Killip class (%)				<0.001			0.807			0.934
1	2014 (92.5)	1018 (81.2)	494 (76.8)		756 (87.3)	758 (87.5)		421 (83.5)	417 (82.7)	
2	124 (5.7)	126 (10.1)	86 (13.4)		78 (9.0)	70 (8.1)		52 (10.3)	56 (11.1)	
3	27 (1.2)	40 (3.2)	29 (4.5)		20 (2.3)	23 (2.7)		18 (3.6)	16 (3.2)	
4	13 (0.6)	69 (5.5)	34 (5.3)		12 (1.4)	15 (1.7)		13 (2.6)	15 (3.0)	
Unstable angina (%)	67 (3.1)	27 (2.2)	29 (4.5)	0.017	20 (2.3)	24 (2.8)	0.647	22 (4.4)	22 (4.4)	1.000
NSTEMI (%)	850 (39.0)	344 (27.5)	291 (45.3)	<0.001	280 (32.3)	268 (30.9)	0.570	221 (43.8)	215 (42.7)	0.751
STEMI (%)	1261 (57.9)	882 (70.4)	322 (50.1)	<0.001	566 (65.4)	574 (66.3)	0.723	261 (51.8)	267 (53.0)	0.753

- 1 Abbreviations: BMI = body mass index; CABG = coronary artery bypass graft; CAD = coronary artery disease;
- 2 CVD = cardiovascular disease; eGFR = estimated glomerular filtration rate; GRACE = Global Registry of
- 3 Acute Coronary Events; IQR = interquartile range; LVEF = left ventricular ejection fraction; MI = myocardial
- 4 infarction; NSTEMI = non-ST-elevation myocardial infarction; PCI = percutaneous intervention; SD = standard
- 5 deviation; STEMI = ST-elevation myocardial infarction
- 6 * Patients matched for: age, sex, diabetes, hypertension, hypercholesterolemia, previous MI, previous PCI,
- 7 previous CABG, previous stroke, previous CVD, valvular disease, chronic lung disease, history of malignancy,
- 8 history of gastrointestinal bleeding, family history of CVD, systolic blood pressure, heart rate, BMI, anaemia,
- 9 Killip class, baseline eGFR, ECG ischemia, smoking, GRACE score, LVEF, type of ACS, PCI vs. balloon
- 10 angioplasty only, percentage stenosis, number of stents, TIMI grade flow post-PCI, presence of coronary
- 11 thrombus.

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Table 2: Treatment summary

TREATMENT CHARACTERISTICS	UNMATCHED				MATCHED					
	ALL DISCHARGE ANAEMIA				HOSPITAL-ACQUIRED ANAEMIA			CHRONIC ANAEMIA		
	No discharge anaemia (n=2178)	HAA (n=1253)	CA (n=643)	p-value	No discharge anaemia (n=866)	HAA (n=866)	p-value	No discharge anaemia (n=504)	CA (n=504)	p-value
PCI - balloon dilatation only	94 (4.3)	69 (5.5)	42 (6.5)	0.051	43 (5.0)	43 (5.0)	1.000	27 (5.4)	27 (5.4)	1.000
Percentage stenosis (%)				<0.001			0.807			0.904
<50%	9 (0.4)	1 (0.1)	1 (0.2)		0 (0.0)	1 (0.1)		0 (0.0)	1 (0.2)	
50-74%	83 (3.8)	50 (4.0)	35 (5.4)		40 (4.6)	37 (4.3)		24 (4.8)	25 (5.0)	
75-94%	350 (16.1)	173 (13.8)	142 (22.1)		121 (14.0)	131 (15.1)		94 (18.7)	95 (18.8)	
95-99%	841 (38.6)	342 (27.3)	216 (33.6)		264 (30.5)	265 (30.6)		182 (36.1)	181 (35.9)	
100%	895 (41.1)	687 (54.8)	249 (38.7)		441 (50.9)	432 (49.9)		204 (40.5)	202 (40.1)	
Stent number (%)				<0.001			0.859			0.781
0	0 (0.0)	3 (0.2)	3 (0.5)		1 (0.1)	1 (0.1)		0 (0.0)	1 (0.2)	
1	1753 (80.5)	882 (70.4)	493 (76.7)		645 (74.5)	643 (74.2)		392 (77.8)	395 (78.4)	
2	349 (16.0)	284 (22.7)	112 (17.4)		170 (19.6)	179 (20.7)		90 (17.9)	87 (17.3)	
≥3	76 (3.5)	84 (6.7)	35 (5.4)		50 (5.8)	43 (5.0)		22 (4.4)	21 (4.2)	
TIMI flow post-PCI (%)				<0.001			0.992			0.267
0	10 (0.5)	23 (1.8)	6 (0.9)		7 (0.8)	6 (0.7)		6 (1.2)	1 (0.2)	
1	12 (0.6)	28 (2.2)	4 (0.6)		8 (0.9)	8 (0.9)		1 (0.2)	2 (0.4)	
2	41 (1.9)	43 (3.4)	19 (3.0)		28 (3.2)	29 (3.3)		14 (2.8)	15 (3.0)	

3	2114 (97.1)	1159 (92.5)	614 (95.5)		823 (95.0)	823 (95.0)		483 (95.8)	486 (96.4)	
Thrombus (%)	924 (42.4)	663 (52.9)	244 (37.9)	<0.001	420 (48.5)	427 (49.3)	0.773	203 (40.3)	204 (40.5)	1.000
Aspirin (%)	2165 (99.5)	1222 (99.3)	616 (98.7)	0.078	861 (99.4)	859 (99.4)	1.000	500 (99.2)	491 (98.8)	0.734
ACE/ARB (%)	2000 (92.0)	1125 (91.5)	569 (91.3)	0.846	798 (92.1)	785 (91.0)	0.424	463 (91.9)	457 (92.1)	0.967
Beta-blocker (%)	1804 (83.0)	1009 (82.1)	502 (80.6)	0.355	728 (84.1)	707 (81.9)	0.262	427 (84.9)	403 (81.2)	0.147
Statin (%)	2165 (99.5)	1214 (98.8)	618 (99.0)	0.043	862 (99.5)	853 (98.8)	0.178	502 (99.6)	493 (99.2)	0.670
P2Y12 agent (%)				<0.001			0.854			0.821
Clopidogrel	829 (38.1)	564 (45.0)	355 (55.2)		360 (41.6)	365 (42.1)		246 (48.8)	252 (50.0)	
Prasugrel	868 (39.9)	481 (38.4)	154 (24.0)		345 (39.8)	349 (40.3)		148 (29.4)	139 (27.6)	
Ticagrelor	481 (22.1)	208 (16.6)	134 (20.8)		161 (18.6)	152 (17.6)		110 (21.8)	113 (22.4)	
Proton pump inhibitor	486 (22.3)	426 (34.6)	266 (42.7)	<0.001	226 (26.1)	268 (31.0)	0.027	143 (28.4)	196 (39.5)	<0.001
Discharge haemoglobin (g/l), median (IQR)	139.00 [133.00, 146.00]	118.00 [108.00, 124.00]	107.00 [92.00, 116.00]	<0.001	135.00 [131.00, 139.00]	119.00 [111.00, 125.00]	<0.001	137.00 [131.00, 143.25]	109.00 [96.00, 117.00]	<0.001
Haemoglobin drop (g/l), median (IQR)	9.00 [4.00, 15.00]	22.00 [14.00, 33.00]	8.00 [3.00, 16.00]	<0.001	7.00 [2.00, 12.00]	23.00 [15.00, 34.00]	<0.001	8.00 [3.00, 15.00]	8.00 [3.00, 15.00]	0.949

- 1 Abbreviations: ACE = angiotensin-converting enzyme; ARB = angiotensin receptor blocker; CABG = coronary
- 2 artery bypass graft; IQR = interquartile range; PCI = percutaneous intervention; SD = standard deviation; TIMI =
- 3 thrombolysis in myocardial infarction;