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# Weekday of gastrectomy and long-term survival in gastric adenocarcinoma

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ABSTRACT

*Background:* Cancer surgery conducted late during the working week might decrease long-term survival for some tumours. Studies on how weekday of gastrectomy influences long-term survival following gastric cancer are few and show conflicting results, which prompted the present investigation.
*Methods:* This population-based cohort study included almost all patients who underwent gastrectomy for gastric adenocarcinoma in Sweden between 2006 and 2015, with follow-up throughout 2020. Associations between weekday of gastrectomy and 5-year all-cause mortality (main outcome) and 5-year disease-specific mortality (secondary outcome) were analysed using multivariable Cox regression. The hazard ratios (HR) with 95% confidence intervals (CI) were adjusted for age, sex, education, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, annual surgeon volume of gastrectomy, and calendar year.
*Results:* Among 1678 patients, surgery on Thursday-Friday was not associated with any statistically significantly increased risk of 5-year all-cause mortality (HR 1.05, 95% CI 0.91–1.22) or 5-year disease-specific mortality (HR 1.04, 95% CI 0.89–1.23) compared to Monday-Wednesday. No associations were found when each weekday was analysed separately, with point estimates close to 1.00 (range 0.98–1.00) Monday-Thursday, but increased for Friday (HR 1.22, 95% CI 0.89–1.68) when fewer patients underwent surgery (4% of all). Stratified analyses by age, comorbidity, tumour stage, neoadjuvant therapy, surgeon volume, and tumour sub-location did not reveal any associations between weekday of surgery on Thursday-Friday compared with Monday-Wednesday and risk of 5-year all-cause mortality.
*Conclusions:* Weekday of gastrectomy might not influence the 5-year survival in patients with gastric adenocarcinoma.


## 1. Introduction

Gastrectomy for gastric adenocarcinoma is technically demanding and adequate surgery is crucial for long-term survival [1,2]. Centralisation of gastric cancer surgery to high-volume centres has reduced postoperative mortality [3–6], highlighting that the prognosis may be influenced by surgeon performance. Survival rates have improved in gastric cancer in many countries over the past decades [7], but the prognosis is still poor and only about half of all patients are alive more than 3–5 years after surgery [1,8]. Uncovering modifiable prognostic factors related to gastrectomy may help to improve long-term survival for these patients.

Some research indicates that survival after surgical procedures, in general, is influenced by the weekday of surgery. Two large cohort studies found worse short-term mortality rates if elective surgery was performed during the latter part of the week [9,10]. Studies have also suggested that a later weekday for cancer surgery decreases the long-term survival rates in some solid tumours, and a cohort study (from our group) found poorer 5-year survival in patients with oesophageal cancer who underwent surgery on later weekdays [11]. Three previous studies have assessed weekday of surgery in relation to long-term survival in gastric cancer, and these

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have provided inconsistent findings, ranging from no association to worse survival after surgery conducted later in the week [12–14]. For studies that have found an association between weekday of surgery and gastro-oesophageal cancer, the risk has been observed mainly for early tumour stages, where the chance for curability is higher [11,14]. The accumulated workload during the working week could lead to tiredness of the surgeons, possibly resulting in a higher risk of tumour-involved resection margins, reduced extent of lymph node removal, and increased risk of postoperative complications, which could all increase the risk for tumour recurrence and earlier death [1,15–17]. Furthermore, patients operated on at the end of the week have their early postoperative recovery over the weekend, when fewer members of the regular staff are present. This may in turn affect the response to acute deterioration and lead to increased sequelae from complications that may develop over weekend periods [18].

In view of the conflicting results and the limited number of studies, we conducted a population-based study with the aim to investigate the hypothesis that a later weekday of curatively intended open gastrectomy decreases the long-term survival in gastric adenocarcinoma.

## 2. Methods

### 2.1. Design

This was a Swedish nationwide population-based cohort study during the study period January 1, 2006 to December 31, 2020. Data came from the Swedish Gastric Cancer Surgery Study (SWEGASS), which has been described in detail elsewhere [8]. In brief, SWEGASS includes 98% of all patients who underwent gastrectomy for gastric adenocarcinoma in Sweden between January 1, 2006 and December 31, 2015, with follow-up until December 31, 2020 for all-cause mortality and December 31, 2019 for disease-specific mortality. Patients were included regardless of elective, acute or emergency surgery. Data sources were medical records and national registries. Potential eligible patients were first identified by a diagnosis code representing gastric adenocarcinoma in the well-validated *Swedish Cancer Registry* [19] or *Swedish Patient Registry* [20,21], combined with a surgical code for gastrectomy, gastric resection, or oesophageal resection in the *Swedish Patient Registry*. Oesophageal cancer was included because gastric cardia cancer could be misclassified as distal oesophageal cancer [22]. The final study cohort was then selected after review of medical records of the patients identified from the registries. Linkages of patients between registries and identification of the medical records were enabled by the unique person identification number system, which provides each Swedish resident with a 10-digit individual identifier. Only gastric adenocarcinoma was included because treatment and prognosis are different to other histological types of gastric malignancy. For the present study, surgery conducted during weekends was excluded. Some additional exclusion criteria were employed to increase the internal validity of the study: patients who underwent minimally invasive gastrectomy (this procedure was used only for selected cases between 2006 and 2015 in Sweden) and surgery without curative intent (where weekday of surgery was unlikely to affect long-term survival). The study was approved by the Ethical Review Board in Stockholm, Sweden (diary number 2017/141–31/2).

### 2.2. Exposure

Data on the weekday of surgery (exposure) were retrieved from the operation charts. Weekday of surgery was categorised in two ways: grouped into early-mid (Monday to Wednesday) and late weekdays (Thursday and Friday), and each weekday separately (Monday, Tuesday, Wednesday, Thursday, and Friday).

### 2.3. Outcomes

The main outcome was 5-year all-cause mortality, which was defined as death from any cause within 5 years of gastrectomy. The secondary outcome was 5-year disease-specific mortality, defined as death from gastric cancer as an underlying or contributing cause of death within 5 years of gastrectomy. The 5-year cut-off for the mortality outcomes was used because deaths occurring later are usually not caused by tumour recurrence [7]. The *Swedish Cause of Death Registry* provided mortality data, which is 100% complete for date of death (for all-cause mortality) and 96% complete for causes of death (for disease-specific mortality) [23].

### 2.4. Covariates

Nine potential *confounders* (with categorisations in parenthesis) were considered: Age (continuous variable), sex (male or female), education ($\leq$9, 10–12, or $\geq$13 years of formal education), comorbidity (Charlson comorbidity index score 0, I, or $\geq$ II), pathological tumour stage (0-I, II, or III-IV), tumour sub-location (non-cardia or cardia), neoadjuvant therapy (yes or no), annual surgeon volume of gastrectomy (in quartiles, i.e. four equal-sized groups), and calendar year (continuous variable). Data on age, sex, pathological tumour stage, tumour sub-location, neoadjuvant therapy, annual surgeon volume of gastrectomy, and calendar year were collected during the review of medical records (including surgical charts, pathology reports, discharge summaries, and reports from multidisciplinary team meetings). The pathological tumour stage was classified according to the 8th edition of American Joint Committee on Cancer (AJCC) Cancer Staging Manual. National registers provided data on the highest attained level of education (the *Longitudinal Integration Database for Health Insurance and Labour Market* [24]) and comorbidities (the *Swedish Patient Registry* [20]). Comorbidities were classified according to the most well-validated version of the Charlson comorbidity index scoring system (not counting the gastric or oesophageal tumours) [25].

Three potential *mediators* (with categorisations in parenthesis), i.e. variables that may explain how weekday of surgery influences the 5-year mortality outcomes, were considered: Resection margin status (tumour-free [R0] or microscopic or macroscopic tumour involvement [R1 or R2]), number of resected and examined lymph nodes (continuous), and postoperative complications according to the well-validated Clavien-Dindo classification of surgical complications (no complication, I-II, III, IV, or V) [26]. Data about these mediators were collected from the medical records.

### 2.5. Statistical analysis

The participating patients were followed up from the date of gastrectomy until death, 5 years after surgery, or end of study period, whichever occurred first. Crude survival probabilities were presented by Kaplan-Meier curves. Cox-proportional hazards regression was used to calculate crude and adjusted hazard ratios (HR) with 95% confidence intervals (CI). The nine potential confounders with the categorisations presented above were adjusted for in the multivariable model (main model). To evaluate whether associations between weekday of gastrectomy and 5-year mortality were modified by strata of age, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, and annual surgeon volume of gastrectomy, an interaction term was included in the multivariable model one by one where HRs were derived within each stratum. For these stratified analyses, each variable was

categorised as stated above except for age and annual surgeon volume of gastrectomy, which were categorised in two groups divided by the median value. Missing values for any of the nine confounders was low (n = 88) and were therefore managed by complete case analysis, i.e. exclusion of patients without complete data on all variables. The proportional hazards assumption was evaluated using log–log survival plots and by calculating the correlations between Schoenfeld residuals for a particular covariate and ranking of individual failure time. The correlations were low, indicating that the proportional hazards assumption was met for all covariates. We planned a mechanistic model with additional adjustment for the three potential mediators, but only in the presence of statistically significant associations in the multivariable analyses. The data management and statistical analyses were conducted according to a pre-defined study protocol and by using the statistical software SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

## 3. Results

### 3.1. Patients

The source cohort included 2154 patients, representing 98% of all patients who underwent gastrectomy for gastric adenocarcinoma between 2006 and 2015 in Sweden. After exclusion of patients who underwent minimally invasive gastrectomy (n = 82), surgery without curative intent (n = 298), procedures performed during weekends (n = 8), and those with missing data in any of the nine confounders (n = 88), the final study cohort consisted of 1678 patients (Fig. 1). Characteristics of these study participants, grouped by early-mid (Monday to Wednesday) and late (Thursday or Friday) weekdays of surgery, are presented in Table 1. There were no major differences in the frequency of any of the covariates comparing these two groups. The 90-day all-cause mortality, 5-year all-cause mortality, and 5-year disease-specific mortality rates were also similar (Table 1 and Fig. 2). Monday and Wednesday were the most common weekdays of surgery (30% and 29%, respectively), while surgery on Fridays was uncommon (4%) (Table 2).

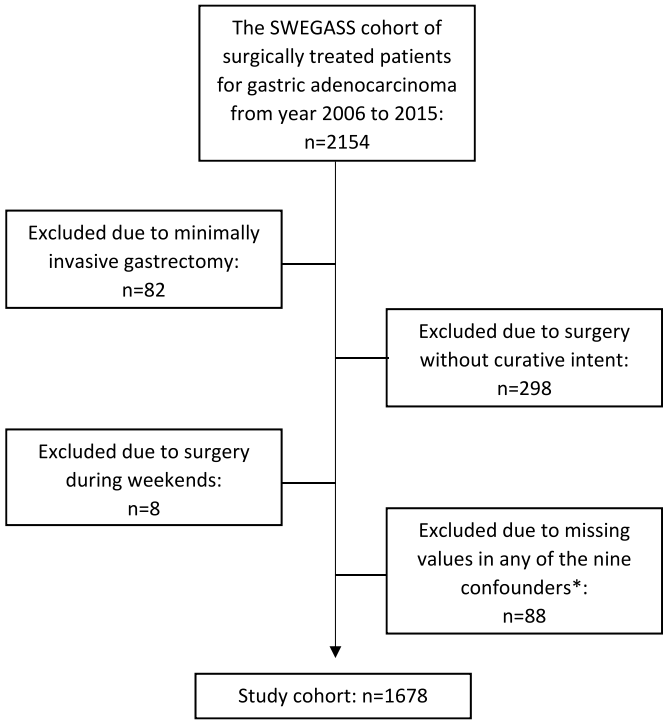


**Fig. 1.** Flowchart illustrating inclusion, exclusions and the final study cohort.
* Age, sex, education, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, annual surgeon volume of gastrectomy, and calendar year.

### 3.2. Weekday of surgery in relation to 5-year survival

Gastrectomy on late weekdays (Thursday or Friday) did not result in any statistically significantly increased risk of 5-year all-cause mortality (adjusted HR 1.05, 95% CI 0.91–1.22) or 5-year disease-specific mortality (adjusted HR 1.04, 95% CI 0.89–1.23)

**Table 1**
Characteristics of study patients who underwent curatively intended open gastrectomy for gastric adenocarcinoma between 2006 and 2015 in Sweden.

| Covariate | Monday-Wednesday Number (%) | Thursday-Friday Number (%) |
|---|---|---|
| Total | 1307 (100) | 371 (100) |
| Confounders | | |
| Age: mean (standard deviation [SD]) | 69 (12) | 69 (12) |
| Sex | | |
| Male | 773 (59) | 214 (58) |
| Female | 534 (41) | 157 (42) |
| Education, years | | |
| ≤9 | 523 (40) | 164 (44) |
| 10–12 | 550 (42) | 152 (41) |
| ≥13 | 234 (18) | 55 (15) |
| Comorbidity (Charlson comorbidity index) | | |
| 0 | 568 (43) | 185 (50) |
| I | 440 (34) | 103 (28) |
| ≥II | 299 (23) | 83 (22) |
| Pathological tumour stage | | |
| 0-I | 370 (28) | 86 (23) |
| II | 406 (31) | 136 (37) |
| III-IV | 531 (41) | 149 (40) |
| Tumour sub-location | | |
| Non-cardia | 1139 (87) | 338 (91) |
| Cardia | 168 (13) | 33 (9) |
| Neoadjuvant therapy | | |
| No | 882 (67) | 275 (74) |
| Yes | 425 (33) | 96 (26) |
| Annual surgeon volume of gastrectomy | | |
| Quartile 1 (<2.25) | 317 (24) | 94 (25) |
| Quartile 2 (2.25 to <4) | 318 (24) | 84 (23) |
| Quartile 3 (4 to <5.75) | 334 (26) | 108 (29) |
| Quartile 4 (≥5.75) | 338 (26) | 85 (23) |
| Calendar year, mean (SD) | 2010 (3) | 2010 (3) |
| ***Mediators*** | | |
| Complications (Clavien-Dindo score) | | |
| No complication | 773 (59) | 241 (65) |
| I-II | 276 (21) | 70 (19) |
| III | 167 (13) | 32 (9) |
| IV | 63 (5) | 16 (4) |
| V | 28 (2) | 12 (3) |
| Resection margin status[a] | | |
| R0 | 1120 (86) | 325 (88) |
| R1/R2 | 121 (9) | 30 (8) |
| Number of resected lymph nodes: mean (standard deviation) | 20 (14) | 20 (14) |
| ***Mortality*** | | |
| 90-day all-cause mortality | | |
| No | 1248 (95) | 347 (94) |
| Yes | 59 (5) | 24 (6) |
| 5-year all-cause mortality | | |
| No | 526 (40) | 141 (38) |
| Yes | 781 (60) | 230 (62) |
| 5-year disease-specific mortality | | |
| No | 631 (48) | 172 (46) |
| Yes | 676 (52) | 199 (54) |

[a] When percentages in one variable do not add up to 100%, this is due to missing data.

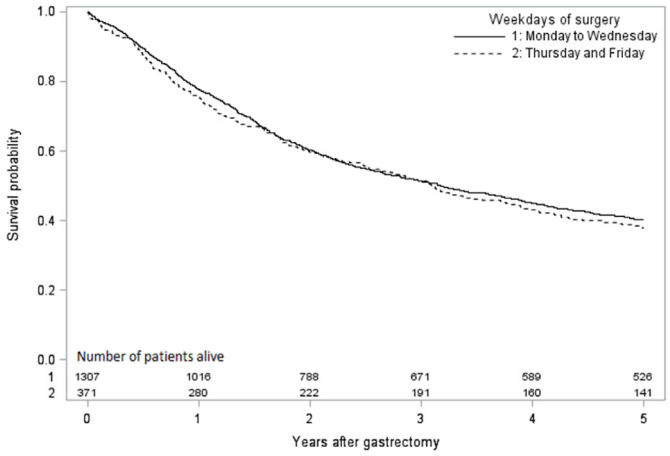


**Fig. 2.** Kaplan-Meier survival curves after gastrectomy for gastric adenocarcinoma stratified by early-mid (Monday to Wednesday) and late (Thursday or Friday) weekdays of surgery.

compared to patients who underwent gastrectomy on early-mid weekdays (Monday to Wednesday) (Table 2).

No statistically significant associations were found when each weekday was analysed separately in relation to 5-year all-cause mortality or 5-year disease-specific mortality (Table 2). The adjusted point estimates for 5-year all-cause mortality were close to 1.00 for surgery on Monday to Thursday (range 0.98–1.00) but was higher on Fridays (HR 1.22, 95% CI 0.89–1.68). The results were similar in the analyses of 5-year disease-specific mortality (Table 2).

The stratified analyses did not reveal any statistically significant associations comparing gastrectomy on late (Thursday and Friday) with early-mid (Monday to Wednesday) weekdays regarding 5-year all-cause mortality in various categories of age, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, or annual surgeon volume of gastrectomy (Table 3).

Because of the lack of any statistically significant associations above, we did not run the mechanistic model with adjustment for potential mediators.

## 4. Discussion

This study found no support for the hypothesis that late weekdays of surgery decreases the 5-year all-cause or disease-specific survival after curatively intended open gastrectomy for gastric adenocarcinoma. The lack of association was consistent across categorisations of weekdays and stratification for potential confounders.

Strengths of this study include the population-based design with high and nationwide completeness, large sample size, adjustment for several prognostic factors, complete follow-up, and accurate information on weekday of gastrectomy (exposure), mortality (outcome), and confounders. Exclusions were done to increase the internal validity of the findings, i.e. other gastric cancer types than adenocarcinoma because these have different treatment and prognosis, minimally invasive surgery because this technique was used only in a few patients who were likely to be selected, and surgery without curative intent where weekday of surgery is unlikely to influence the long-term survival. Among weaknesses is the risk of unknown or residual confounding, a concern shared by most observational studies. However, confounders - by definition associated with both the exposure and the outcome, and not mediators - were unlikely to be strongly associated with weekday of surgery. Therefore, it was not surprising that the adjusted and crude risk estimates were similar. We did not adjust for adenocarcinoma subtypes (Laurén classification) or postoperative oncological treatment. However, histological classification is less good compared to the pTNM staging system (used in this study) for prognostic prediction [1,27], and postoperative oncological treatment was partly accounted for when adjusting for age, tumour stage, comorbidity, and neoadjuvant therapy. Patients who underwent emergency surgery could have caused some heterogeneity, but after exclusion of non-curative gastrectomies, such patients should be few if any, and would not strongly influence the results. Type II errors could contribute to the null findings, but this is contradicted by the large sample size and the consistency of results in all analyses. However, the low rate of gastrectomies conducted on Fridays reduced the statistical power for the analyses of this weekday, and the point estimates of mortality after surgery on a Friday were increased. Thus, the lack of association with survival for surgery on Fridays is more uncertain.

**Table 2**
Weekday of gastrectomy for gastric adenocarcinoma and risk of 5-year mortality presented as hazard ratios (HR) with 95% confidence intervals (CI).

| Weekday | Number (%) | 5-year all-cause mortality | |
|---|---|---|---|
| | | Crude HR (95% CI) | Adjusted HR (95% CI)[a] |
| Monday-Wednesday | 1307 (78) | 1.00 (reference) | 1.00 (reference) |
| Thursday-Friday | 371 (22) | 1.06 (0.92–1.23) | 1.05 (0.91–1.22) |
| Monday | 499 (30) | 1.00 (reference) | 1.00 (reference) |
| Tuesday | 325 (19) | 0.96 (0.80–1.15) | 0.98 (0.81–1.17) |
| Wednesday | 483 (29) | 1.02 (0.87–1.20) | 0.99 (0.84–1.16) |
| Thursday | 303 (18) | 1.03 (0.86–1.24) | 1.00 (0.83–1.21) |
| Friday | 68 (4) | 1.17 (0.86–1.60) | 1.22 (0.89–1.67) |
| | | **5-year disease-specific mortality** | |
| | | **Crude HR (95% CI)** | **Adjusted HR (95% CI)[a]** |
| Monday-Wednesday | 1307 (78) | 1.00 (reference) | 1.00 (reference) |
| Thursday-Friday | 371 (22) | 1.06 (0.91–1.24) | 1.04 (0.89–1.23) |
| Monday | 499 (30) | 1.00 (reference) | 1.00 (reference) |
| Tuesday | 325 (19) | 0.90 (0.74–1.09) | 0.91 (0.75–1.11) |
| Wednesday | 483 (29) | 0.96 (0.80–1.14) | 0.94 (0.79–1.11) |
| Thursday | 303 (18) | 1.00 (0.83–1.22) | 0.97 (0.80–1.19) |
| Friday | 68 (4) | 1.07 (0.76–1.51) | 1.11 (0.78–1.57) |

[a] Adjusted for age, sex, education, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, annual surgeon volume of gastrectomy, and calendar year.

**Table 3**
Weekday of gastrectomy for gastric adenocarcinoma and risk of 5-year all-cause mortality presented as adjusted hazard ratios (HR) with 95% confidence intervals (CI), stratified by covariates.

| Variable | Number (%) | Monday-Wednesday (reference) | Thursday-Friday Adjusted HR (95% CI)[a] |
|---|---|---|---|
| Age (median, year) | | | |
| <71 | 830 (49) | 1.00 | 1.06 (0.85–1.32) |
| ≥71 | 848 (51) | 1.00 | 1.04 (0.85–1.27) |
| Comorbidity (Charlson comorbidity index) | | | |
| 0 | 753 (45) | 1.00 | 0.98 (0.79–1.23) |
| I | 543 (32) | 1.00 | 1.03 (0.78–1.36) |
| ≥II | 382 (23) | 1.00 | 1.19 (0.90–1.58) |
| Pathological tumour stage | | | |
| 0-I | 456 (27) | 1.00 | 1.06 (0.68–1.64) |
| II | 542 (32) | 1.00 | 1.00 (0.77–1.29) |
| III-IV | 680 (41) | 1.00 | 1.08 (0.88–1.31) |
| Tumour sub-location | | | |
| Non-cardia | 1477 (88) | 1.00 | 1.04 (0.89–1.22) |
| Cardia | 201 (12) | 1.00 | 1.14 (0.72–1.80) |
| Neoadjuvant therapy | | | |
| No | 1157 (69) | 1.00 | 1.05 (0.89–1.24) |
| Yes | 521 (31) | 1.00 | 1.05 (0.78–1.42) |
| Annual surgeon volume of gastrectomy (median, number) | | | |
| <4 | 813 (48) | 1.00 | 1.06 (0.86–1.31) |
| ≥4 | 865 (52) | 1.00 | 1.04 (0.84–1.28) |

[a] Adjusted for age, sex, education, comorbidity, pathological tumour stage, tumour sub-location, neoadjuvant therapy, annual surgeon volume of gastrectomy, and calendar year.

To our knowledge, only three previous studies have investigated whether weekday of gastrectomy influences long-term survival in gastric cancer. Two of these found no associations [12,13], but a cohort study from China of 463 patients found worse survival in early-stage tumours (stage I and II) among patients who underwent gastrectomy on later weekdays compared to earlier weekdays [14]. The seemingly contradictory findings could be explained by higher frequencies of gastrectomies on Fridays (24%) and early-stage tumours in later weekdays in the Chinese study compared to the present investigation. Further, one Dutch study found decreased lymph node removal on later weekdays [13]. However, in the present study, the distribution of lymph node yield as well as resection margin status and complication rates and other variables were similar when comparing early and late weekdays. Moreover, the multivariable adjustment did not change the results. Thus, lymph node removal or other potential covariates should not explain the results.

The lack of association between weekday of gastrectomy for gastric adenocarcinoma in the present study combined with the results of the three earlier studies on the topic suggests that it is safe to conduct these procedures on any of the weekdays Monday to Thursday, whereas Friday might still not be an ideal weekday for gastrectomy.

In conclusion, this large and population-based cohort study indicates that any weekday of curatively intended open gastrectomy for gastric adenocarcinoma does not influence the 5-year survival, at least not between Monday and Thursday.

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## CRediT authorship contribution statement

**Wilhelm Leijonmarck:** Data curation, Methodology, Writing – original draft. **Johannes Asplund:** Data curation, Methodology, Writing – review & editing. **Sheraz R. Markar:** Supervision, Writing – review & editing. **Fredrik Mattsson:** Methodology, Formal analysis, Software, Validation, Writing – review & editing. **Jesper Lagergren:** Conceptualization, Methodology, Supervision, Funding acquisition, Writing – review & editing.

## Declarations of competing interest

None.

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