

Supplementary Material for analysis of Anti-Xa and APTTr anticoagulation on VV-ECMO patients

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Table of contents

1	VARIABLES	2
1.1	Outcome variables	2
1.2	Calculated variables	3
1.3	Independent Variables	3
1.4	Time related variables	3
2	DATA SOURCE	3
3	ASSUMPTIONS & DEFINITIONS	4
3.1	Assumptions	4
3.1.1	Assumption 1 : each patients receive only 1 ECMO run	4
3.1.2	Assumption 2: all ECMO pump speed run times are accurate with automatic entry to EHR system	4
3.1.3	Assumption 3: All blood products transfusion are documented.	4
3.2	Definitions	4
3.2.1	Outcome variables	4
3.2.2	Independent Variables	5
3.2.3	Targets of anticogulation	6
3.2.4	Blood related variables	7
4	DATA CLEANING PROCESS	7
5	DESCRIPTIVE ANALYSIS	7
6	MULTIVARIATE MODELS	9
6.1	Outcome 1a : Time-in-Therapeutic-Range (TTR)	9
6.1.1	Model : multi-variate beta regression (family of generalised linear models)	10

6.1.2	Interpretation	10
6.1.3	Beta regression assumptions	10
6.1.4	Variable Dispersion	11
6.1.5	Fit assessment	11
6.2	Outcome 1b : Variability of Anticoagulation as VGR	11
6.2.1	Model : Multivariable linear regression with outcomoe log transformed and interpreted accordingly	12
6.2.2	Interpretation	12
6.2.3	Choice of model and assumptions	12
6.2.4	Fit assessment	13
6.3	Outcome 2a : Rate of bleeding and thrombotic events	13
6.3.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	13
6.4	Outcome 2b : Rate of only bleeding events	14
6.4.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	14
6.5	Outcome 2c : Rate of only thrombotic events	14
6.5.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	14
6.6	Outcome 2d : Rate of ECMO circuit change	15
6.6.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	15
6.7	Outcome 2e : Cumulative Dose of Heparin	16
6.7.1	Model : Multivariate linear regression with log transformed outcome and interpreted accordingly	16
6.7.2	Model Choice	16
6.7.3	Fit assessment	17
6.7.4	Interpretation	17
6.8	Outcome 2f : Rate of change of heparin prescriotion	17
6.8.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	17
6.9	Outcome 2g : Rate of blood products transfused per ECMO duration	18
6.9.1	Model : Multivariate Poisson distribution using ecmo duration as offset . . .	18
6.10	Outcome 2h : Time to any bleeding or thrombotic complication	18
6.10.1	Model : Multivariate Cox proportional hazards model	18
6.11	On modelling VGR	20
6.12	On Using Poisson models with offset	20

1 VARIABLES

1.1 Outcome variables

1. Bleeding or thrombotic events(BTE)

1a. no BTE

1b. only haemorrhagic complications

1c. only thrombotic complications

1d. both BTE

2. ECMO circuit changes

3. Heparin Prescription 3a. cumulative dose of heparin 3b. heparin prescription changes

4. Blood products consumption

1.2 Calculated variables

1. Time in Therapeutic Range (Rosendaal Method)

2. Variability in Anticoagulation (Fihn's method)

1.3 Independent Variables

1. Demographics (age, sex, ethnicity, height, weight, BMI etc)

2. Blood variables (Full blood count results, renal function, CRP , etc)

3. Anticoagulation related variables (all the APTTr and anti-Xa results)

1.4 Time related variables

- time to any bleeding or thrombotic event
- time to only bleeding events
- time to only thrombotic event
- time to ECMO circuit change

2 DATA SOURCE

- Electronic health records data extraction from GSTT systems using ECMO pump speed as definition of cases.
- Cases cross-checked with ECMO VV referral system database.
- Complications individually reviewed where relevant.
- Electronic health records accessed through GDPR compliant system and saved in encrypted work spaces.
- All investigation results (CT imagings, blood results) in between ECMO run times are extracted.
- All prescription related data (e.g., heparin infusions are extracted to the nearest hour)

3 ASSUMPTIONS & DEFINITIONS

3.1 Assumptions

3.1.1 Assumption 1 : each patients receive only 1 ECMO run

- verified through discussion with clinicians at regular mortality and morbidity meeting

3.1.2 Assumption 2: all ECMO pump speed run times are accurate with automatic entry to EHR system

- verified through daily clinical use
- Thus, this time period is used as a basis to calculate other times in relation.

3.1.3 Assumption 3: All blood products transfusion are documented.

- Mandated by NHS Blood transfusion all blood product transfusions are explicitly documented.
- This was used to verify and cross-check ECMO run times and related complications.
- all blood products prescribed and given are checked and confirmed if there are discrepancies.
- Assumed that the blood product is given in whole – e.g., if 1 unit Packed Red blood cells are prescribed, it is assumed the whole unit is given.

3.2 Definitions

3.2.1 Outcome variables

3.2.1.1 Bleeding and Thrombotic Complications

Any relevant bleeding and thrombotic complications simultaneously occurring and documented in medical notes are recorded and nearest most accurate time period extracted.

This does not include complications sustained through ECMO cannulation process nor incurred through retrieval process.

In addition, relevant complications identified incidentally through cross sectional imaging are also supplemented.

EOLIA definition of bleeding complications restrict to bleeding events requiring transfusion of blood products.

Our definition of bleeding complication is more broad. This is to allow analysis at granular scale.

We separately analyse blood products transfusion as a proxy marker of complications.

3.2.1.2 Time to events

Our analysis is to answer the question of the impact of monitoring tool after being established on anticoagulation for VV ECMO.

As a result, our time to “first” BTE is defined as the first BTE after having established on VV ECMO. Thus, the complications at admission associated to pre-ECMO status or associated to cannulation is not counted. The time starts at the time of successful cannulation and arrival to GSTT ECMO unit and ends at the time of first BTE.

Similarly, the ECMO circuit change is counted as the first circuit change after being established on VV ECMO.

3.2.1.3 ECMO circuit changes

Similarly, documentation of ECMO circuit changes and rationales were extracted.

3.2.1.4 Heparin administrations

All administration of heparin prescribed under different regimes were extracted and relevant units obtained.

Regimes	Description	Units
1	Heparin	units per hour
2	Heparin ECMO Xa IV Infusion	units per kilogram per hour
3	Heparin IV injection	units
4	Heparin RR INF 20000 IU	units
5	Heparin systemic Inf 20000 Units	units per hour

Table of heparin administration types.

3.2.2 Independent Variables

3.2.2.1 Height and Weight

Original documentaion of height and weight on ECMO cannulation were used due to likely later variation of patients through out their critical illness.

3.2.2.2 Time in Therapeutic Range (Rosendaal method)

Time in Therapeutic Range is an intuitive measure for evaluating the quality of anticoagulation. Multiple definitions exist.

Traditional definition is effectively no of tests in range as numerator divided by total no of tests. This does not take into account different durations that patient are anticoagulated for. Thus, Rosendaal et al has calculated a linear interpolation method incorporating duration of measurements.

TTR is a value of range between 0 to 100%.

Each individual time period between each anticoagulation blood test was calculated to the nearest hour.

Then Time in Range for that period was calculated. Finally, for each patient and their ECMO duration, the cumulative TTR was calculated.[7]

$$Time\ in\ Therapeutic\ Range_{Rosendaal} = \frac{Time\ in\ range}{Total\ Time}$$

No of anticoagulation blood tests per day was calculated to detect anomalous results. When outlier values were noted and duplicate record with non outlier value was found, this was chosen and randomly verified manually.

3.2.2.3 Variability of Anticoagulation (Fihn's method of Variance Growth rate)

$$\sigma^2 = \frac{1}{n} \sum_{i=1}^n \frac{(value_i - target)^2}{\tau_i}$$

Variance Growth Rate is a derivation of a statistical measure “variance” adjusted for each individual time period.[1]

For each value of anti-coagulation test result, this was subtracted from target and squared, then divided by time period. Summary of all of this for the entire duration of ECMO was then calculated to generate a final value of VGR for each patient.

The benefit of Variance Growth Rate is that this does not assume the patient to be in a target range(which TTR does). VGR calculates how “far” each value is from target range adjusted for time period.

3.2.3 Targets of anticogulation

For aPTTr : target range 1.5 to 2.0 is thus, target value 1.75 is chosen as midpoint and

For anti-Xa : target range 0.3 to 1.0 is , and mid point 0.65 is chosen as target value

3.2.4 Blood related variables

- All blood related variables are extracted and first 24 hour blood values summarised.

4 DATA CLEANING PROCESS

All relevant variables and time-stamps are verified to be within ECMO run times.

Categorical variables are summarised and visualised. Numeric variables are summarised and visualised to allow for visual inspection of distribution (e.g., normal distribution or kurtosis).

If data is transformed (e.g., log transformation), post transformation distribution is visualised

Count data is visualised and modeled as poisson / quasi-poisson distribution.

Correlation between numerical values are visualised with correlograms and pearson coefficients calculated.

5 DESCRIPTIVE ANALYSIS

Supplementary Table of the first 24-hour admission blood results variables

Blood investigation variables	aPTTr group (N=74)	anti-Xa group (N=180)	p Value
Haemoglobin (g/L)			
Mean (SD)	101 (15.2)	99.8 (14.8)	0.656
Median [Min, Max]	99.8 [71.0, 139]	98.0 [70.5, 147]	
Platelets (10 ⁹ /L)			
Mean (SD)	152 (94.9)	231 (102)	<0.001
Median [Min, Max]	141 [17.0, 390]	219 [0, 495]	
Neutrophils (10 ⁹ /L)			
Mean (SD)	9.26 (7.29)	12.0 (5.44)	<0.001
Median [Min, Max]	7.48 [0.100, 41.9]	11.0 [0.950, 31.9]	

Blood investigation variables	aPTTr group	anti-Xa group	p Value
Fibrinogen (g/L)			
Mean (SD)	4.89 (2.16)	5.49 (2.49)	0.086
Median [Min, Max]	4.70 [0, 9.70]	5.38 [0.500, 11.8]	
Lactate dehydrogenase (U/L)			
Mean (SD)	616 (405)	793 (1130)	0.389
Median [Min, Max]	528 [0, 2390]	558 [0, 9840]	
Ferritin (ug/L)			
Mean (SD)	2200 (5150)	2760 (5320)	<0.001
Median [Min, Max]	70.0 [0, 36200]	1330 [0, 51500]	
Creatinine Kinase (umol/L)			
Mean (SD)	2200 (4380)	2640 (23600)	0.00771
Median [Min, Max]	620 [0, 22600]	327 [0, 317000]	
C-reactive protein (mg/L)			
Mean (SD)	223 (106)	178 (147)	0.00292
Median [Min, Max]	213 [53.5, 515]	151 [0, 622]	
Procalcitonin (ug/L)			
Mean (SD)	16.2 (29.1)	6.90 (15.9)	0.033
Median [Min, Max]	2.79 [0, 100]	0.913 [0, 91.6]	
Bilirubin (umol/L)			
Mean (SD)	21.3 (19.9)	17.2 (30.4)	0.0666
Median [Min, Max]	14.0 [0, 127]	11.0 [0, 389]	
Albumin (g/L)			
Mean (SD)	24.6 (3.86)	26.7 (3.99)	<0.001
Median [Min, Max]	24.0 [15.5, 35.0]	27.0 [18.0, 39.5]	
Creatinine (umol/L)			

Blood investigation variables	aPTTr group	anti-Xa group	p Value
Mean (SD)	170 (117)	120 (106)	<0.001
Median [Min, Max]	146 [34.0, 671]	75.3 [21.0, 626]	
eGFR (needed)			
Mean (SD)	58.0 (45.6)	89.8 (55.2)	<0.001
Median [Min, Max]	38.8 [6.00, 208]	91.3 [0, 330]	
Corrected Calcium (umol/L)			
Mean (SD)	2.34 (0.147)	2.30 (0.283)	0.0851
Median [Min, Max]	2.36 [1.83, 2.64]	2.32 [0, 3.01]	
Bicarbonate (mmol/L)			
Mean (SD)	24.9 (5.51)	28.1 (3.97)	<0.001
Median [Min, Max]	23.4 [10.7, 38.6]	28.2 [15.0, 37.6]	
Lactate (mmol/L)			
Mean (SD)	3.10 (3.34)	1.85 (1.39)	0.342
Median [Min, Max]	1.60 [0.700, 18.2]	1.60 [0.600, 16.8]	
pH			
Mean (SD)	7.37 (0.0604)	7.36 (0.553)	<0.001
Median [Min, Max]	7.37 [7.06, 7.46]	7.40 [0, 7.47]	

6 MULTIVARIATE MODELS

6.1 Outcome 1a : Time-in-Therapeutic-Range (TTR)

Table 3: TTR multivariable analysis

ttrgf			
Predictors (Intercept)	Estimates	95% CI	p Value
	0.56	0.20 – 1.54	0.26
age	1.01	1.00 – 1.03	0.14

ttrgf			
sex [M]	0.78	0.59 – 1.05	0.10
bmi	1.01	0.99 – 1.03	0.28
apache	0.99	0.95 – 1.03	0.63
group [gaxa]	0.95	0.68 – 1.32	0.74
rrt [yes]	0.60	0.43 – 0.85	<0.01
ecmod	1.01	1.00 – 1.02	0.01
Observations	254		
R ²	0.087		

6.1.1 Model : multi-variate beta regression (family of generalised linear models)

6.1.2 Interpretation

Membership of anti-Xa group decreases by 0.95 the odds of having a larger TTR. Each additional day on ECMO increases the odds of having a larger TTR by 1.01. Receipt of renal replacement therapy decreases the odds of having a large TTR by 0.6.

6.1.3 Beta regression assumptions

TTR is a value of range between 0 to 100%. Thus, beta-regression is used, using {betareg} package.

TTR includes values including 0 and 100%, whereas strictly beta-regression does not include values 0 or 100%. Thus, data-transformation $y1 = y * n-1) + 0.5$ / as per Smithson and Vekuijen was carried out.[8]

It was hypothesised that 1. age 2. BMI 3. sex 4. apache II score 5. monitoring group 6. renal replacement therapy 7. duration on ecmo 8. admission period median pH value

are likely to affect “time-in-therapeutic range”

Beta regression model using above 8 variables were fitted. Step-wise variable selection was undertaken using Akaike Information Criteria. Likelihood ratio test {lmtest} using function “lrtest” was used to evaluate final model against a null model.

Likelihood ratio test confirms that p-value of final model is 0.000171 compared to null model.

In this model, variables “sex, renal replacement therapy, and duration of ECMO” are the only variables that have statistical significance. Thus, a reduced model using only this 3 variables were fitted.

Reduced model and full models were compared using likelihood ratio test and there were not statistically significant differences.

Reduced model AIC was lower than full model AIC by 5 points. As a result, we have selected a full variable model for its ability to infer effects of biologically plausible variables such as age, sex.

APACHE 2 score already includes pH value and APACHE 2 score was not known to be predictive of outcome in ECMO patients. Thus, sensitivity analysis was undertaken with both variables - APACHE 2 score and median pH value. Models were evaluated using AIC and likelihood ratio test. Likelihood ratio tests found that model including only APACHE score without pH variable has the lowest chi-square value and is statistically significant ($p < 0.0001$).

Thus, this model was selected further.

6.1.4 Variable Dispersion

In the final model, dispersion parameter - phi coefficient- was estimated at 2.27 and was statistically significant. The most likely variable contributing to dispersion was 'duration of ecmo'.

Thus, final model was re-fitted with the same mean equation but now with duration of ECMO as additional regressor for the precision parameter - phi.

The model including of ecmo duration as regressor for the precision parameter was statistically significant and improved a model fit, without significant difference in estimates of other parameters. AIC of this new model was significantly lower than model without precision parameter.

Thus, there was a statistically significant evidence for variable dispersion, and thus was chosen as a final model.

6.1.5 Fit assessment

Maximum likelihood estimation was used to calculate p-values.

Model assumptions were also evaluated using diagnostic plots; and was graphically satisfactory for normal assumption, homoskedasticity, and influential observations effects.

Heteroskedasticity was also checked numerically using studentized Breusch-Pagan test and demonstrated no evidence of heteroskedasticity.

Multicollinearity was assessed using variable inflation factors using {car} package function "vif". All variables have VIF score < 2 demonstrating no evidence of multicollinearity.

Link function of logit is used.

6.2 Outcome 1b : Variability of Anticoagulation as VGR

Table 4: Multivariable analysis of VGR

sigm 2			
Predictors	Estimates	95% CI	p Value
(Intercept)	-0.61	-1.99 – 0.77	0.39
age	0.00	-0.01 – 0.01	0.98
bmi	0.01	-0.01 – 0.03	0.40
apache	0.01	-0.03 – 0.05	0.64
sex [M]	-0.02	-0.31 – 0.27	0.89
group [gaxa]	-2.04	-2.38 – -1.70	<0.01
alb median	0.01	-0.03 – 0.05	0.54
lactate median	0.11	0.04 – 0.18	<0.01
plt median	0.00	-0.00 – 0.00	0.29
rrt [yes]	0.22	-0.14 – 0.58	0.23
ecmod	-0.00	-0.01 – 0.01	0.68
Observations	253		
R ² / R ² adjusted	0.504		
	/		
	0.484		

6.2.1 Model : Multivariable linear regression with outcomoe log transformed and interpreted accordingly

6.2.2 Interpretation

Variability of anticoagulation is a measure of quality of anticoagulation, with lower Variability results in better control of anticoagulation. For 1 unit increase in lactate, our variability increases by 10.6% membership in anti Xa decreases variability by 86%.[\[3\]](#)

6.2.3 Choice of model and assumptions

Variability of anticoagulation was significantly right skewed thus, a natural logarithmic transformation was undertaken of dependent variable and then a linear model was fitted against.

It was hypothesised that 1. age 2. BMI 3. sex 4. apache II score 5. monitoring group 6. renal replacement therapy 7. duration on ecmo

were thought to be affecting variability of anticoagulation.

On a multi-variate modelling, as evaluated by AIC and likelihood ratio tests, monitoring group and lactate are the only two statistically significant variables.

Thus, a reduced model using only statistically significant model was evaluated against a full model - there were no improvement of a reduced model. And, due to ability to infer effects of other biologically plausible variables, age, bmi, apache etc are included in a final model.

6.2.4 Fit assessment

Multiple R squared value of fitted model was 0.5 and model was statistically significant, whilst R squared value is not encouraging, it offers a bility to infer the reduction in variability in anti-Xa group whilst adjusting for other variables.

Model assumptions were checked for normality, heteroskedasticity, effect of outlying values and distribution of residuals.

Numerical check of final model using Breusch-Godfrey test confirmed visual findings that model residuals are homoskedastic.

6.3 Outcome 2a : Rate of bleeding and thrombotic events

6.3.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Dependent variable is selected for “any” bleeding and thrombotic events. Each event is considered as seperate event, thus discrete count.

Table 5: Rate of any bleeding or thrombotic events

abte			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.17	0.06 – 0.46	<0.01
age	1.01	0.99 – 1.02	0.25
sex [M]	0.72	0.55 – 0.95	0.02
bmi	0.99	0.97 – 1.01	0.37
apache	0.98	0.94 – 1.02	0.30
group [gaxa]	1.07	0.77 – 1.50	0.70
ttrg	0.16	0.10 – 0.25	<0.01
sigm	0.99	0.96 – 1.01	0.55
rrt [yes]	1.37	0.99 – 1.88	0.05
Observations	254		
R ² Nagelkerke	0.327		

Given the count nature of “events” data, a dependent variable is visualised and found to conform to poisson distribution. Thus, this is modeled as multivariable poisson regression using a standard “log” link function.

However, it is important to note that there are statistically significant differences and variation of ECMO duration between two different study groups. The longer duration on ECMO, the longer the duration of anticoagulation and the potential risk of any complication is higher.

This is taken into account by using an “offset” of ecmo duration.

As per above, model assumptions checked.

6.4 Outcome 2b : Rate of only bleeding events

6.4.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Table 6: Only haemorrhagic complication events

toth			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.02	0.00 – 0.11	<0.01
age	1.03	1.00 – 1.05	0.02
sex [M]	0.87	0.56 – 1.37	0.53
bmi	1.01	0.98 – 1.04	0.48
apache	1.00	0.94 – 1.06	0.90
group [gaxa]	0.64	0.37 – 1.12	0.12
ttrg	0.12	0.06 – 0.25	<0.01
sigm	0.86	0.70 – 0.99	0.10
rrt [yes]	1.51	0.93 – 2.44	0.09
Observations	254		
R ² Nagelkerke	0.276		

As per above but restricted to analysis of only “haemorrhagic complications”. Similar treatment was followed.

6.5 Outcome 2c : Rate of only thrombotic events

6.5.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Table 7: Thrombotic Complications only

totthr			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.28	0.07 – 1.11	0.07
age	1.00	0.98 – 1.02	0.85
sex [M]	0.57	0.39 – 0.83	<0.01
bmi	0.98	0.95 – 1.00	0.06
apache	0.95	0.90 – 1.00	0.07
group [gaxa]	1.57	0.96 – 2.64	0.08
ttrg	0.22	0.12 – 0.43	<0.01
sigm	1.00	0.98 – 1.01	0.82
rrt [yes]	1.34	0.85 – 2.09	0.21
Observations	254		
R ² Nagelkerke	0.180		

As per above, but for only thrombotic complications.

6.6 Outcome 2d : Rate of ECMO circuit change

6.6.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Table 8: ECMO circuit change analysis

totc			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.04	0.01 – 0.12	<0.01
age	1.01	1.00 – 1.02	0.14
sex [M]	1.19	0.89 – 1.60	0.25
bmi	1.01	1.00 – 1.03	0.15
apache	0.97	0.93 – 1.01	0.17
group [gaxa]	0.68	0.48 – 0.95	0.02
ttrg	0.92	0.56 – 1.51	0.73
sigm	0.97	0.90 – 1.01	0.32
rrt [yes]	1.30	0.94 – 1.79	0.10
Observations	254		
R ² Nagelkerke	0.108		

The next or first ECMO circuit change after cannulation on VV ECMO first are modelled against independent variables.

The ECMO circuit change events are modelled as count data - poisson regression- is used again using ecmo duration as an offset.

6.7 Outcome 2e : Cumulative Dose of Heparin

6.7.1 Model : Multivariate linear regression with log transformed outcome and interpreted accordingly

Table 9: Cumulative dose of heparin - log transformed

<div> <div>cud</div> <div>2</div> </div>			
Predictors	Estimates	95% CI	p Value
(Intercept)	11.38	10.78 – 11.97	<0.01
age	-0.00	-0.01 – 0.01	0.71
sex [M]	0.13	-0.04 – 0.29	0.12
bmi	0.01	-0.00 – 0.02	0.12
group [gaxa]	0.10	-0.15 – 0.35	0.44
lactate median	-0.13	-0.17 – -0.09	<0.01
ecmod	0.04	0.04 – 0.05	<0.01
ttrg	0.78	0.43 – 1.13	<0.01
sigm [log]	0.03	-0.05 – 0.10	0.52
Observations	232		
R ² / R ² adjusted	0.689		
	/		
	0.678		

6.7.2 Model Choice

- log transformed of heparin dose given a significantly skewed distribution of heparin.
- Given the likely interaction of duration of ecmo, interaction between ecmo duration and TTR & ecmo duration and VGR are included in an extended model.
- The model fit is not improved and the interactions are not statistically significant.
- Thus, the reduced model without interaction effects are chosen.

6.7.3 Fit assessment

- Linear regression fit assessment as per AIC, and likelihood ratio tests.

6.7.4 Interpretation

Given log transformation of dependent variable, the effect size is interpreted as a percentage change.

6.8 Outcome 2f : Rate of change of heparin prescription

6.8.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Table 10: Analysis of heparin prescription changes

runl			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.72	0.37 – 1.35	0.31
age	1.00	0.99 – 1.00	0.25
sex [M]	1.01	0.87 – 1.17	0.93
bmi	1.00	0.99 – 1.01	0.80
group [gaxa]	1.37	0.91 – 2.10	0.14
lactate median	0.94	0.89 – 1.00	0.04
ttrg	3.11	1.74 – 5.74	<0.01
sigm	1.01	1.00 – 1.01	0.01
rrt [yes]	1.12	0.94 – 1.33	0.19
group [gaxa] × ttrg	0.28	0.14 – 0.53	<0.01
Observations	254		
R ² Nagelkerke	0.665		

Rate of change of heparin prescription is modelled as count data, poisson generalised model, with an offset for ecmo duration.

The interaction between TTR and monitoring is found. It is statically significant with $p < 0.001$ and thus included.

6.9 Outcome 2g : Rate of blood products transfused per ECMO duration

6.9.1 Model : Multivariate Poisson distribution using ecmo duration as offset

Our definition of BTE is more relaxed than ELSO definition since we count all documented and imaged BTEs. The ELSO definition of bleeding event is defined as that requiring blood product transfusion.

Given the predominance of red blood cell transfusion over other blood products and given we are looking at overall effect on coagulation, we have modelled all blood together summatively.

Table 11: Total blood products transfused

bldtot			
Predictors	Incidence Rate Ratios	95% CI	p Value
(Intercept)	0.36	0.22 – 0.59	<0.01
age	1.00	1.00 – 1.01	0.08
sex [M]	1.05	0.94 – 1.18	0.37
bmi	0.99	0.99 – 1.00	0.04
apache	1.05	1.03 – 1.06	<0.01
rrt [yes]	1.61	1.42 – 1.83	<0.01
cudose	1.00	1.00 – 1.00	0.03
ttrg	0.24	0.16 – 0.36	<0.01
sigm [log]	1.07	1.02 – 1.12	<0.01
group [gaxa]	0.78	0.60 – 1.01	0.05
ttrg × group [gaxa]	1.57	1.01 – 2.44	0.05
Observations	232		
R ² Nagelkerke	0.943		

Blood products consumption were modelled as a count data using multivariate poisson regression.

The interaction were found between time in therapeutic range and monitoring group and was statistically significant.

6.10 Outcome 2h : Time to any bleeding or thrombotic complication

6.10.1 Model : Multivariate Cox proportional hazards model

Given the frequency of BTEs in any ECMO population and clinicians tendency to change “anticoagulation targets” after a BTE event (e.g., a thrombotic event may warrant a higher therapeutic target

and a bleeding event may warrant a pause in anticoagulation or a lowering of anticoagulation target).

As a result, we have analysed the time to first BTE, this is because it is likely that after the first BTE, anticoagulation targets are likely to be adjusted and thus affecting on TTR and VGR by clinical team.

The BTE detected through admission CT scan are not counted as this is likely to be due to pre ECMO or cannulation related events whether anticoagulation may not have been started.

Similar rationale is discussed in the literature to delineate BTE associated with ECMO from other concurrent events such as procedures, surgery or initial cannulation period.^[6]

With this assumptions, we explored time to BTE using multivariable cox proportional hazards model.

Table 12: Cox model for time to first any BTE

Predictors	Dependent variable		
	Estimates	95% CI	p Value
age	1.03	1.00 – 1.05	0.04
sexM	0.92	0.58 – 1.46	0.72
rrtyes	1.16	0.63 – 2.13	0.63
bmi	0.99	0.96 – 1.01	0.32
groupgaxa	0.97	0.56 – 1.67	0.90
apache	0.94	0.87 – 1.01	0.08
ttrg	0.17	0.07 – 0.41	<0.01
sigm	1.00	0.96 – 1.03	0.79
Observations	192		
R ² Nagelkerke	0.098		

The duration on ECMO is one of the major factors influencing the analysis of time to “first” BTE in ECMO.

Duration on ECMO is highly variable with significant outliers with long tail distribution where some patients surviving ECMO after over 50 days. COVID pneumonitis patients in our population would also be over-represented given their higher absolute numbers and longer duration of ECMO time.

Our median time on ECMO is 11 and 17 days respectively for aPTTr and AXA groups. This is consistent with a large multi-centre international study evaluating ECMO in COVID-19 pneumonitis with over 844 ECMO patients reporting a median time on ECMO as 13 days.^[9]

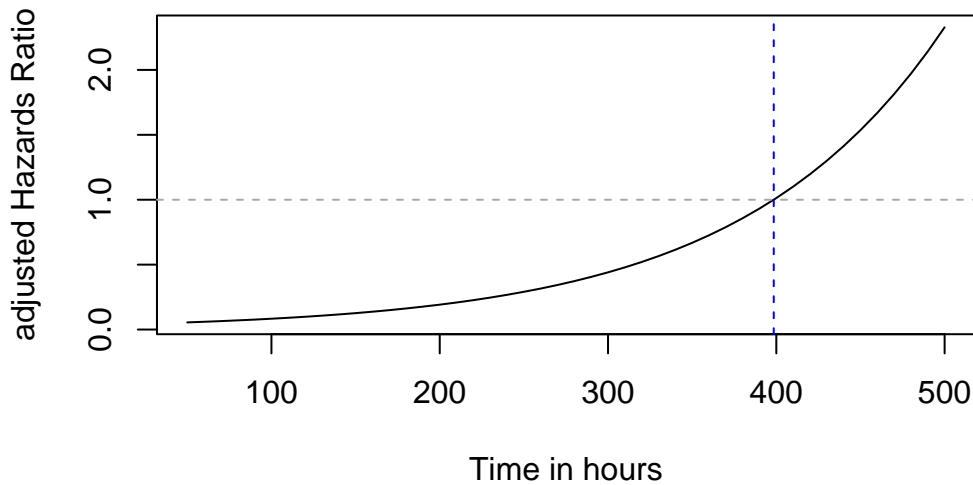
As a result, we have undertaken a pragmatic cut off of 20.8 days (500 hours).

This results in 192 patients who have 92 BTE events within this period.

The major findings from our model are that age is associated with higher risk of bleeding and thrombotic outcome (adjusted Hazard Ratio 1.03, $p = 0.042$), and higher value of time in therapeutic range is protective against having BTE in the initial period (adjusted HR 0.17, $p < 0.001$).

However, TTR has an statistically significant ($p = 0.0261$) interaction with time and the initial protective effect of high TTR changes after a certain period on ECMO.

Effects of TTR over time



6.11 On modelling VGR

Variance Growth Rate is a summary value with ranges including 0 and is significantly skewed. The statistical methods used in modelling skewed distribution is commonly to undertake “log transformation”. Hence, most of the literature that analyses VGR uses log-transformed i.e., log VGR. [2] [razouki_improving_2014] [van_miert_effect_2020].

Whilst this is a successful statistical treatment for vitamin K antagonists, where target range is usually > 1 this does not always apply to our data where our target range has values < 1 .

Given the minimal impact of VGR in this study and given the ease of interpretability of non-transformed VGR, we have only performed log transformation where relevant as an acceptable trade off to overall assess the impact of VGR and TTR.

6.12 On Using Poisson models with offset

Given a significant differences in median duration of ECMO between two population, it is prudent to adjust for this effect whilst analysing events (“counts”)

An intuitive treatment would be a simply using ECMO duration as a denominator to the events, however, a simple division assumes linearity (e.g., if 1 circuit change or 1 transfusion of red cells in 3 days, then would expect a 2nd circuit change or 2nd transfusion by day 6)

Therefore, we have modeled using a ECMO duration as “offset” in Poisson models. This is a commonly accepted approach and routinely used in analysis of similar circumstances. For example, Nijman (2022) using poisson modes to calculate emergency room attendances during COVID 19 pandemic whilst using population as “offset” to adjust for case-mix differences. [5] Kanankege(2022) used a human population as offset in Poisson model of high risk areas for dog-mediated rabies.[4]

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