Final Report

Group 5

November 29, 2024

Introduction

Scientific Question:

Does the relationship between EtCO2 and AMC behave differently in the presence of relevant medical history?

Clinical relevance:

Observing the relationship between EtCO2 (end-tidal carbon dioxide) and AMC (area of maximum compression) is crucial to understanding the quality of chest compression during CPR (cardiopulmonary resuscitation), a life-saving procedure during cardiac arrests. Chest compressions are crucial to reviving a patient or achieving ROSC or Return to Spontaneous Circulation, though they requires adequate rate, depth, and location for the best results. However, CPR guidelines are not as precise, as differences in body size and histories of chronic disease can alter the heart's location. When patients have compression in the aortic root, there is an obstruction of blood flow from the heart and can limit effective perfusion and worsen the prognosis. Compressions over the left ventricle or LV can improve the blood circulation and lead to higher-quality CPR. This relationship between EtCO2 (where higher levels have been shown to correlate with better blood flow from past studies) and AMC may differ dependent on a patient's history, as these conditions can impact the ventilation-perfusion mismatch or other presenting symptoms.

Methods

Design of Study:

The metabolic syndrome and cognitive function study is a retrospective observational analysis which focuses on investigating the relationship between EtCO2 and the AMC during CPR and whether this relationship is affected by the presence of relevant medical histories of patients.

This study focuses on 2 primary areas of compression, the left ventricle (LV) and the left ventricle outflow tract (LVOT)/aortic root, and how compression over these AMCs impact EtCO2 levels and whether this impact changes by the CPR patients' pre existing medical conditions, such as coronary artery disease, congestive hearth failure, chronic kidney disease, diabetes mellitus and myocardial infarction.

Data set Details:

The data set consists of 129 cases of in-hospital cardiac arrests where transesophageal echocardiography (TEE) imaging was employed during CPR. This advanced imaging technique is used to identify the specific area of the chest targeted for compression to precisely classify the AMC - LV or LVOT.

Key variables in the data set include:

- Dependent Variable:
  - EtCO2: Measured during CPR, represents levels of exhaled CO2 and serves as a proxy for cardiac output.
- Independent Variables:
  - AMC: Areas of compression, classified as either LV or LVOT.
  - Medical History: Binary indicators for conditions like coronary artery diseas (hist1), congestive hearth failure (hist2), chronic kidney disease (hist3), diabetes mellitus (hist4), and myocardial infarction (hist5).
- Covariates:
  - Demographics like race and gender.
  - TEE operator experience level (e.g. attending physicain, resident, etc.).
  - Type of CPR performed (manual, mechanical, alternating).
  - Timing of cardiac arrest (known or approximated).

First, the data set underwent pre-processing and cleaning, which included the removal of invalid data entries. The next step involved converting the numeric values flagged as outliers (e.g. placeholder values like 9999) to missing (NA) values and excluding them from the analysis.

Cohort:

The study cohort consisted of adult patients who had experienced in-hospital cardiac arrest and received CPR where TEE was used. The inclusion criteria required proper TEE imaging data to identify the precise location of AMC and valid measurements of EtCO2 levels. patients with any significant missing data were excluded. After pre-processing and cleaning, the data set included 106 valid observations (patients) for further analysis.

Analysis Methodology:

A multivariable linear model was implemented to analyse the relationship between EtCO2 level and AMC. Interaction terms between AMC the the medical history variables were used in this model to asses whether the relationship between EtCO2 and AMC varied by the presence of 5 specific pre-existing medical conditions.

The analysis included two models:

- A reduced model, which included only the main effects of AMC and medical history.
- A full model, which included interaction terms to evaluate whether medical history affected the relationship between EtCO2 and AMC.

An Analysis of Variance (ANOVA) test was used to compare these models and evaluate the contribution of the interaction terms to model fit.

Rationale:

A linear regression model was implemented based on the assumption that the relationship between EtCO2 and AMC is linear, as CO2 levels in the blood reflect cardiac output which is influnced by the area of compression (LV or LVOT). We assume higher EtCO2 levels when the AMC is LV. This specif approach allows for testing the main effects while including interaction terms to study more complex relationships. The inclusion of these interaction terms is very crucial for identifying whether specif medical histories alter the impact of AMC on EtCO2.

Assumptions include:

- Linearity and Homoscedasticity: Checked via residual plots.
- Independence: Verified using the Durbin-Watson test.
- Normality of Residuals: Assessed through Q-Q plots.
- Multicollinearity: Evaluated using Variance Inflation Factors (VIF), with all predictors having suitable values (< 5).

This methodological approach addresses potential confounding factors and statistical validity while guaranteeing a thorough investigation of the research question.

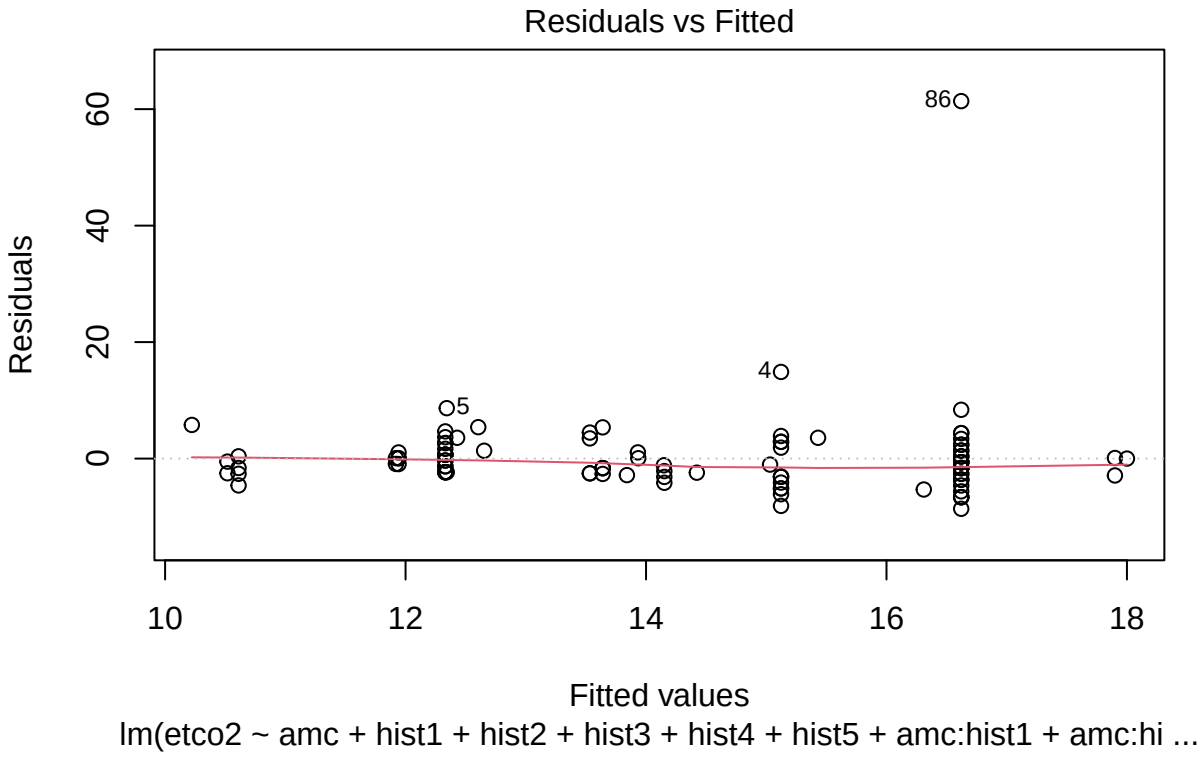
Cleaning

Assumptions Made:

```
##
## Call:
## lm(formula = etco2 ~ amc + hist1 + hist2 + hist3 + hist4 + hist5 +
##     amc:hist1 + amc:hist2 + amc:hist3 + amc:hist4 + amc:hist5,
##     data = cleaned_data)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -8.621 -2.619 -0.931  1.370 61.379
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    16.6214     1.1944  13.916   <2e-16 ***
## amcLVOT/Aortic root            -4.2908     2.0445  -2.099   0.0385 *
## hist1Yes                        1.2787     3.5284   0.362   0.7179
## hist2Yes                       -2.4692     3.1609  -0.781   0.4367
## hist3Yes                       -1.5898     3.0474  -0.522   0.6031
## hist4Yes                       -1.4986     2.0872  -0.718   0.4745
## hist5Yes                        2.8772     7.6651   0.375   0.7082
## amcLVOT/Aortic root:hist1Yes   -2.9982     4.5376  -0.661   0.5104
## amcLVOT/Aortic root:hist2Yes    2.7653     5.1711   0.535   0.5941
## amcLVOT/Aortic root:hist3Yes    3.2874     4.4888   0.732   0.4658
## amcLVOT/Aortic root:hist4Yes    1.1099     3.6059   0.308   0.7589
## amcLVOT/Aortic root:hist5Yes   -0.6706     9.0707  -0.074   0.9412
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 7.439 on 94 degrees of freedom
## Multiple R-squared:  0.08144,    Adjusted R-squared:  -0.02605
## F-statistic: 0.7576 on 11 and 94 DF,  p-value: 0.6807
```

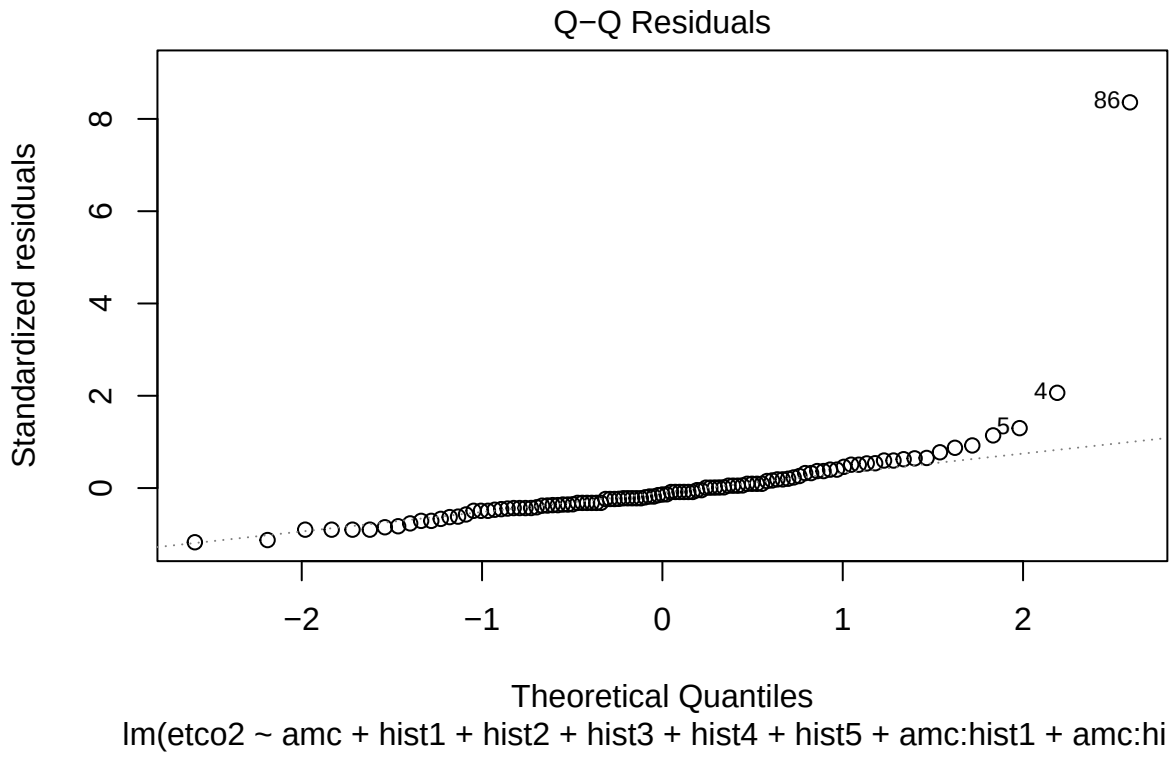
1. Linearity and Homoscedasticity (Constant Variance) The relationship between the predictor(s) (independent variables) and the outcome (dependent variable) should be linear. This means that changes in the predictor(s) should produce proportional changes in the outcome.For homoscedasticity, the variance of the residuals (errors) should be constant across all levels of the independent variables.



2. Independence: The residuals (errors) from the model should be independent. This means that the error associated with one observation is not correlated with the error of another observation. A value close to 2 indicates no autocorrelation.

```
##
##  Durbin-Watson test
##
## data:  normal_model
## DW = 1.9764, p-value = 0.4561
## alternative hypothesis: true autocorrelation is greater than 0
```

3. Normality of Residuals: The residuals should be normally distributed.



4. No Perfect Multicollinearity: The independent variables should not be highly correlated with each other. If they are, it becomes difficult to isolate the individual effects of each predictor. In ANOVA, this is typically not an issue if the independent variables are categorical (factors), but in multiple regression, it could be.

VIF < 5: Acceptable (low multicollinearity). VIF between 5 and 10: Moderate multicollinearity, may warrant investigation. VIF > 10: Problematic (high multicollinearity), often considered a "bad" value.

```
##           GVIF Df GVIF^(1/(2*Df))                    Interacts With
## amc   1.000000 11        1.000000 hist1, hist2, hist3, hist4, hist5
## hist1 3.442607  3        1.228800                                amc
## hist2 3.502840  3        1.232358                                amc
## hist3 3.650231  3        1.240852                                amc
## hist4 2.752329  3        1.183814                                amc
## hist5 2.341210  3        1.152321                                amc
##                 Other Predictors
## amc                           --
## hist1 hist2, hist3, hist4, hist5
## hist2 hist1, hist3, hist4, hist5
## hist3 hist1, hist2, hist4, hist5
## hist4 hist1, hist2, hist3, hist5
## hist5 hist1, hist2, hist3, hist4

##       amc     hist1     hist2     hist3     hist4     hist5 amc:hist1 amc:hist2
##  1.898921  3.650137  2.193650  2.616744  1.960386  4.086208  3.959051  2.301842
```

```
## amc:hist3 amc:hist4 amc:hist5
##  3.297204  3.510846  4.333708
```

Results

Tables Figures Statistics

Exploratory/Descriptive Analysis: Main Statistical Analysis:

The p-value (0.5541) for the F-test is larger than the typical significance threshold of 0.05, meaning the addition of the interaction terms (amc:hist1 and amc:hist3) does not significantly improve the model. The RSS difference between the two models is relatively small (63.984), suggesting that the interactions do not provide a substantial increase in explanatory power.

However. the Residual sum of squares (RSS) which measures the total deviation of the predicted values from the actual values, is lower for Model 2 (5224.8) compared to Model 1 (5288.8), indicating a marginal improvement in fit when the interaction terms are included.

```
## Analysis of Variance Table
##
## Model 1: etco2 ~ amc + hist1 + hist2 + hist3 + hist4 + hist5
## Model 2: etco2 ~ amc + hist1 + hist2 + hist3 + hist4 + hist5 + amc:hist1 +
##     amc:hist3
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     99 5288.8
## 2     97 5224.8  2    63.984 0.5939 0.5541
```


```
## Analysis of Variance Table
##
## Model 1: etco2 ~ amc + hist1 + hist2 + hist3 + hist4 + hist5
## Model 2: etco2 ~ amc + hist1 + hist2 + hist3 + hist4 + hist5 + amc:hist1 +
##     amc:hist3
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     99 5288.8
## 2     97 5224.8  2    63.984 0.5939 0.5541
```


Conclusions

Main Findings: Answer Scientific Question: Limitations:

References

Citations References