Gasto cardíaco por ECOTT vs Fick

Parte 2: Análisis principales Gasto Cardíaco

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# Cardiac Output

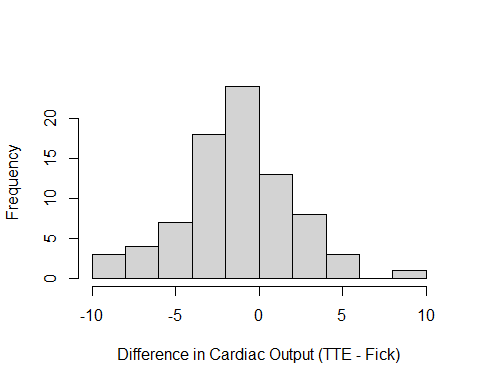
The distribution of cardiac output values for both methods is skewed as shown bellow.

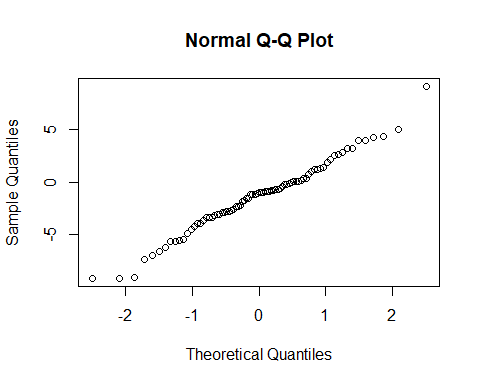
|  |  |
| --- | --- |
| TTE  TTE | Fick  Fick |

Thus, bootstrapping is used to calculate the mean with 95% CI:

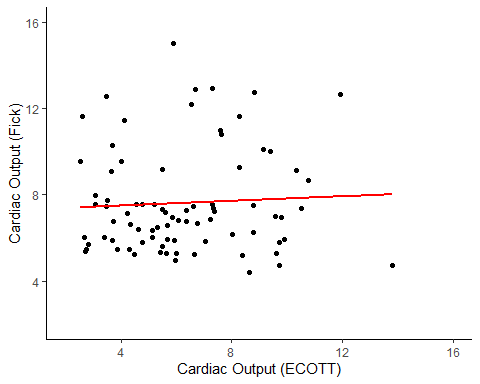
The mean cardiac output for TTE is 6.26 L/min (95% CI: 5.73 to 6.81), and for Fick, 7.62 L/min (95% CI: 7.14 to 8.18).

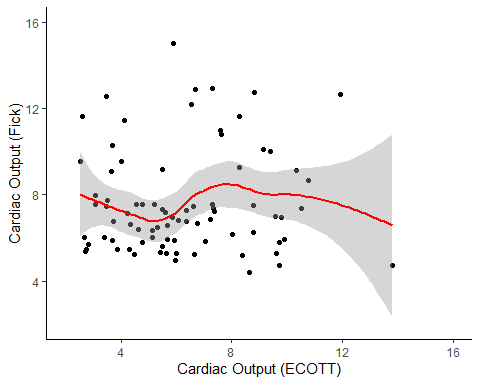
However, the distribution of differences between the two methods is approximately normal.





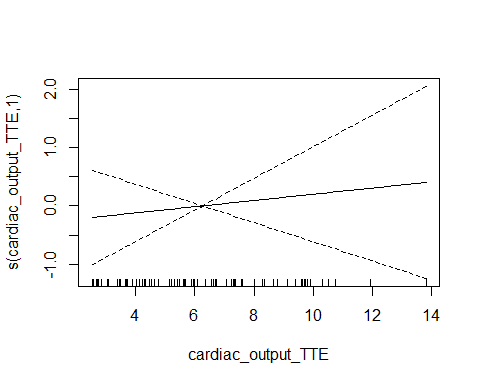
Assuming a linear and non-linear relationship





Examine if non-linear term is significantly better than linear term

Family: gaussian   
Link function: identity   
  
Formula:  
cardiac\_output\_Fick ~ s(cardiac\_output\_TTE)  
  
Parametric coefficients:  
 Estimate Std. Error t value Pr(>|t|)   
(Intercept) 7.6173 0.2674 28.49 <2e-16 \*\*\*  
---  
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
  
Approximate significance of smooth terms:  
 edf Ref.df F p-value  
s(cardiac\_output\_TTE) 1 1 0.24 0.626  
  
R-sq.(adj) = -0.00959 Deviance explained = 0.303%  
GCV = 5.9362 Scale est. = 5.7896 n = 81



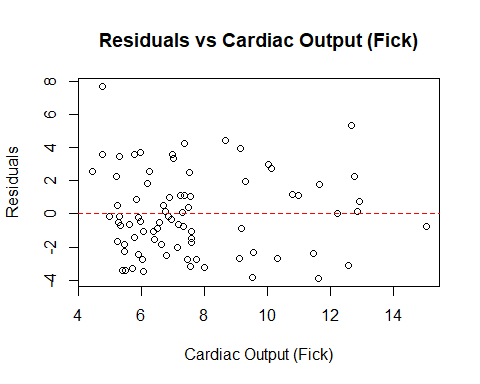
Non-linear relationship is not significantly better than linear relationship. Thus, I will model as linear relationship.

# Pearson correlation

Pearson's product-moment correlation  
  
data: data$cardiac\_output\_TTE and data$cardiac\_output\_Fick  
t = 0.48997, df = 79, p-value = 0.6255  
alternative hypothesis: true correlation is not equal to 0  
95 percent confidence interval:  
 -0.1652936 0.2701451  
sample estimates:  
 cor   
0.05504239

# Linear regression

Call:  
lm(formula = cardiac\_output\_TTE ~ cardiac\_output\_Fick, data = data)  
  
Residuals:  
 Min 1Q Median 3Q Max   
-3.8979 -1.8550 -0.3494 1.8022 7.7202   
  
Coefficients:  
 Estimate Std. Error t value Pr(>|t|)   
(Intercept) 5.82344 0.92636 6.286 1.67e-08 \*\*\*  
cardiac\_output\_Fick 0.05688 0.11608 0.490 0.626   
---  
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
  
Residual standard error: 2.486 on 79 degrees of freedom  
Multiple R-squared: 0.00303, Adjusted R-squared: -0.00959   
F-statistic: 0.2401 on 1 and 79 DF, p-value: 0.6255



# Linear Mixed Effects Model

Linear mixed model fit by REML ['lmerMod']  
Formula: cardiac\_output\_Fick ~ cardiac\_output\_TTE + (1 | ID) + (1 | time\_point)  
 Data: data  
  
REML criterion at convergence: 345.9  
  
Scaled residuals:   
 Min 1Q Median 3Q Max   
-1.70612 -0.35805 -0.09272 0.25930 2.18064   
  
Random effects:  
 Groups Name Variance Std.Dev.  
 ID (Intercept) 3.170 1.780   
 time\_point (Intercept) 5.995 2.448   
 Residual 1.240 1.114   
Number of obs: 81, groups: ID, 52; time\_point, 9  
  
Fixed effects:  
 Estimate Std. Error t value  
(Intercept) 9.13612 1.18262 7.725  
cardiac\_output\_TTE -0.01155 0.09538 -0.121  
  
Correlation of Fixed Effects:  
 (Intr)  
crdc\_tp\_TTE -0.570

# Intraclass correlation coefficient (ICC)

Average Score Intraclass Correlation  
  
 Model: twoway   
 Type : agreement   
  
 Subjects = 81   
 Raters = 2   
 ICC(A,2) = 0.0917  
  
 F-Test, H0: r0 = 0 ; H1: r0 > 0   
 F(80,79.6) = 1.12 , p = 0.312   
  
 95%-Confidence Interval for ICC Population Values:  
 -0.325 < ICC < 0.39

# Coefficient of variation (CV) and coefficient of error (CE)

The following calculation is the coefficient of variation (CV) for the overall averaged measurements, expressed as percentage:

Fick CV: 31.44%

TTE CV: 39.55%

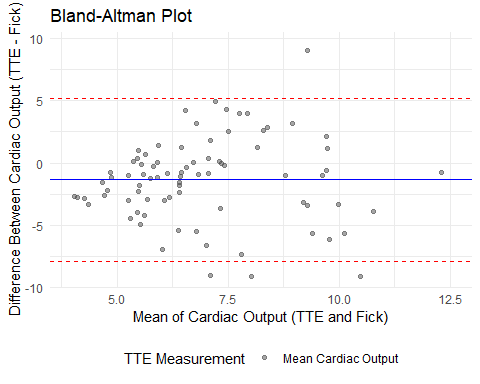
Because there are multiple measurements that are averaged to produce the mean cardiac output for TTE, we can calculate the coefficient of error (CE) as suggested by Cecconi, et al.1 The following calculations reproduce the structure of the table in their review article:

| ID | CO 1 (TTE), L/min | CO 2 (TTE), L/min | CO 3 (TTE), L/min | Mean CO TTE, L/min | CV (%) | CE (%) | CO (Fick method), L/min |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 6.41 | 7.24 | 6.24 | 6.63 | 8.02 | 4.63 | 5.24 |
| 2 | 14.72 | 13.11 | 13.61 | 13.81 | 5.96 | 3.44 | 4.74 |
| 2 | 9.93 | 9.87 | 9.31 | 9.70 | 3.52 | 2.03 | 4.74 |
| 3 | 3.37 | 3.55 | 3.43 | 3.45 | 2.74 | 1.58 | 12.58 |
| 3 | 3.95 | 4.10 | 4.03 | 4.03 | 1.83 | 1.05 | 9.57 |
| 4 | 2.69 | 2.81 | 2.61 | 2.71 | 3.74 | 2.16 | 5.37 |
| CE: Coefficient of Error; CV: Coefficient of Variation; TTE: Transthoracic Echocardiography. | | | | | | | |

The mean CV of TTE for the repeated measurements per patient was 7.3% (95% CI: 6.2 to 8.7) and the CE was 4.2% (95% CI: 3.6 to 5), corresponding to a precision of 8.4% (95% CI: 7.2 to 10.1).

# Bland-Altman Plot

#### Bland Altman-single measure

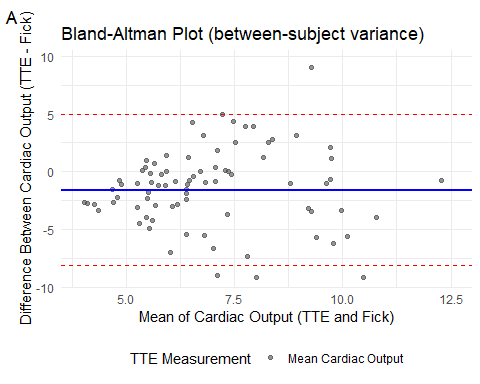


##### Systematic bias (Paired t-test)

Paired t-test  
  
data: data$cardiac\_output\_TTE and data$cardiac\_output\_Fick  
t = -3.6582, df = 80, p-value = 0.0004534  
alternative hypothesis: true mean difference is not equal to 0  
95 percent confidence interval:  
 -2.1007836 -0.6204367  
sample estimates:  
mean difference   
 -1.36061

#### Bland Altman-repeated measures (random effects for between-subject variance)

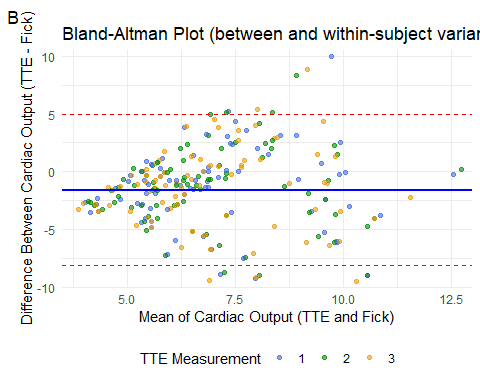
Linear mixed model fit by REML ['lmerMod']  
Formula: differences ~ 1 + (1 | ID)  
 Data: data  
  
REML criterion at convergence: 409.7  
  
Scaled residuals:   
 Min 1Q Median 3Q Max   
-2.33206 -0.35646 -0.01357 0.29854 2.12253   
  
Random effects:  
 Groups Name Variance Std.Dev.  
 ID (Intercept) 6.149 2.480   
 Residual 4.909 2.216   
Number of obs: 81, groups: ID, 52  
  
Fixed effects:  
 Estimate Std. Error t value  
(Intercept) -1.5811 0.4384 -3.606



#### Bland Altman-repeated measures (random effects for between-subject variance and within-subject variance)

Linear mixed model fit by REML ['lmerMod']  
Formula:   
differences ~ 1 + (1 | ID) + (1 | ID:time\_point) + (1 | TTE\_measurement)  
 Data: data\_long  
  
REML criterion at convergence: 765.2  
  
Scaled residuals:   
 Min 1Q Median 3Q Max   
-2.87065 -0.39608 -0.02016 0.39620 2.35851   
  
Random effects:  
 Groups Name Variance Std.Dev.  
 ID:time\_point (Intercept) 4.8084 2.1928   
 ID (Intercept) 6.1494 2.4798   
 TTE\_measurement (Intercept) 0.0000 0.0000   
 Residual 0.3033 0.5508   
Number of obs: 243, groups: ID:time\_point, 81; ID, 52; TTE\_measurement, 3  
  
Fixed effects:  
 Estimate Std. Error t value  
(Intercept) -1.5811 0.4384 -3.606  
optimizer (nloptwrap) convergence code: 0 (OK)  
boundary (singular) fit: see help('isSingular')

There was singularity in the prior model including a random effect for within-subject TTE measurements. Because this term is conceptually important to take into account the nested structure of the data, we will keep it in the model. Other alternatives would be to include it as a fixed effect, but this would not necessarily represent a meaningful variable to model.



# Mean absolute difference (MAD)

The MAD for cardiac output is 2.8 (95% CI: 2 to 3.5).

# Mean absolute percentage error (MAPE) and precision of Fick method

Precisionb (point estimate): 56.84 %

Precisionb (95% CI): 44.34 - 74.22 %

# Summary

The mean cardiac output with TTE was 6.26 (95% CI: 5.73 to 6.81) L/min, and 7.62 L/min (95% CI: 7.14 to 8.18) for the Fick method. The correlation between the two methods was rho = 0.06 (95% CI: -0.17 to 0.27, p=0.626). In a linear mixed model with random patient slopes, there was a change in Fick CO of -0.01 (95% CI: -0.2 to 0.18) L/min for each unit change in mean TTE CO. The ICC between TCE and Fick CO 0.09 (95% CI: -0.32 to 0.39).

The mean absolute difference in CO between TTE and Fick was 2.76 (95% CI: 2 to 3.5) L/min. The coefficient of variation for an individual measurement of TTE was 39.5% and 31.44% for Fick. The mean CV of TTE for the repeated measurements per patient was 7.3% (95% CI: 6.2 to 8.7) and the CE was 4.2% (95% CI: 3.6 to 5), corresponding to a precision of 8.4% (95% CI: 7.2 to 10.1). The MAPE of the Fick method compared to TTE was 57.5% (95% CI: 45.5 - 74.6). The precision of the Fick method was 56.84% (95% CI: 44.34 to 74.22). The LSC was 11.9% (95% CI: 10.1 to 14.3) for TTE and 80.4% (95% CI: 62.7 to 105) for the Fick method.

**Figure 1** shows the Bland-Altman plot for the repeated measures model with random effects for between-subject variance (Figure1A) and within-subject variance (Figure1B). The mean difference (systematic bias) between TTE and Fick CO was -1.58 (95% CI: -2.44 to -0.72, p = 0) L/min, with 95% limits of agreement of -8.16 to 5 L/min.

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