Review Article

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RECEIVER OPERATING CHARACTERISTIC CURVE ANALYSIS IN DIAGNOSTIC RESEARCH: A REVIEW

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ABSTRACT

Optimal dose selection in clinical trials is problematic when efficacious and toxic concentrations are close. A receiver operating characteristic curve is a graphical technique used to identify the optimal cut-off point for a continuous variable. Implementation of ROC analysis is currently possible using various statistical software packages. However, the process is straightforward in the EZR package of R software. This present study aims to provide a tutorial using a simple example and a detailed description of the procedure in EZR software. The information provided can help the researchers perform the analysis independently.

Keywords: ROC curve, diagnostic test, sensitivity, specificity

INTRODUCTION

Optimal dose selection in clinical trials is problematic when efficacious and toxic concentrations are close. The receiver operating characteristic (ROC) curve is a graphical technique used to identify the optimal cut-off point for a continuous variable to distinguish between two diagnostic groups (disease/ no disease) of a binary variable[1,2]. The concept of the ROC curve was developed in the early 1950s. The very first application was found in radar, in which the ROC curve analysis was used to distinguish between noise such as birds or other environmental objects and actual enemy aircraft[3,4]. Implementation of ROC analysis is currently possible using various statistical software packages. However, the process is straightforward in the EZR package of R software. This present study aims to provide a tutorial using a simple example and a detailed description of the procedure in EZR software. The information provided can help the researchers perform the analysis independently.

Description of ROC curve

To produce the ROC curve, first, estimate the sensitivity and specificity[5,6] for each continuous variable of interest values. Then plot a line diagram by keeping sensitivity (actual positive rate) on Y-axis and 1−specificity (false positive rate) on X-axis, which will result in the ROC curve as given in Figure 1. Thus, ROC allows exploring the relationship between sensitivity and specificity of a clinical test for various cut-off points.

Each point on the ROC curve represents a sensitivity/(1−specificity) pair corresponding to a particular decision threshold. The area under the ROC curve (AUC) measures how well the continuous variable of interest can distinguish between two diagnostic groups (disease/ no disease).

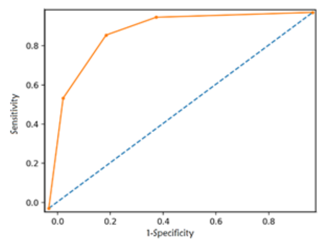


Figure 1: ROC curve

The area under the curve is a measure of test accuracy. Closer the curve to the left-hand border and top border of the ROC space, the more accurate the test. A perfect test has an area of 1.0; a non-discriminating test (one which falls on the diagonal) has an area of 0.5. The accuracy of the test will reduce while the curve gets closer to the diagonal[7,8]. The accuracy of the test can be interpreted based on the range of area under the ROC curve, as given in Table 1.

Table 1: Interpretation of accuracy of the test based on a range of AUC value

AUC	Interpretation
Less than 0.70	Poor
0.70 o 0.80	Fair
0.80 o 0.90	Good
0.90 to 1.00	Excellent

Uses of the ROC curve

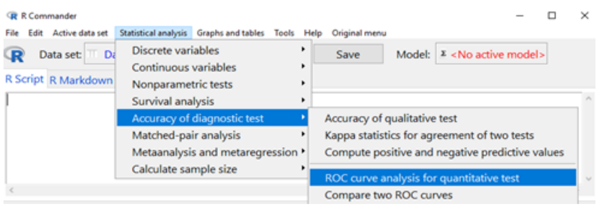
- Allows the determination of the cut-off point at which optimal sensitivity and specificity are achieved.
- Allows an assessment of the diagnostic accuracy of a test.
- Allows the comparison of the usefulness of two or more diagnostic tests.

Example: Suppose a researcher is interested in determining how good systolic blood pressure (SBP) is in predicting the Myocardial Infarction (MI) status (Yes/No). The objective here is to determine an optimum cut-off value for SBP. A sample of hypothetical data used for the demonstration is provided in Table 2.

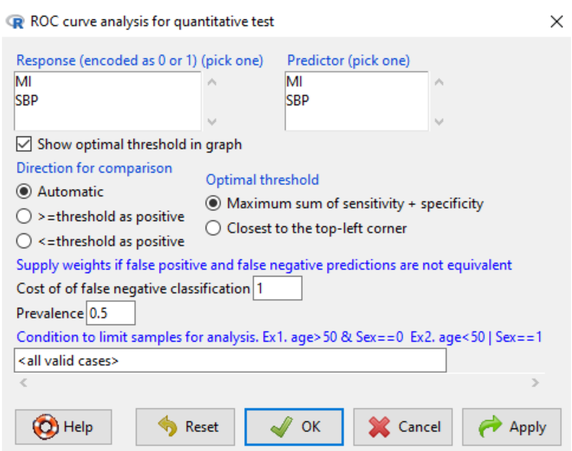
Table 2: Sample of hypothetical data used to produce ROC curve

ID	MI	SBP
1	Present	122
2	Present	125
3	Absent	143
4	Absent	123
5	Present	133
6	Absent	123
7	Present	124
8	Present	125
9	Present	126
10	Absent	122

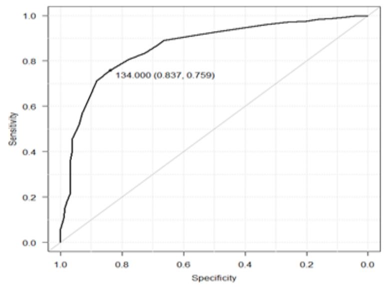
Solution: Step 1: Open the dataset in EZR and go to Statistical analysis > Accuracy of diagnostic test > ROC curve analysis for the quantitative test.



Step 2: Select the variable MI in 'Response' and SBP' option 'Predictor' and click 'OK'.



Step 3: The output window displays the area under the ROC curve with 95% CI. The ROC curve (plot) provides the optimum cut-off value, specificity, and sensitivity.



Step 4: Report the results: The area under the curve is 0.86 (95% CI: 0.84, 0.89). Hence it can be concluded that SBP is a good predictor of MI. The optimum cut off value for SBP is 134, with a specificity of 84% and sensitivity of 76%.

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Area under the curve 0.862 95% CI 0.837 - 0.888
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CONCLUSION

The receiver operating characteristic curve is a commonly used method in medical research. In this paper, the theory of the ROC curve is illustrated in a simplified way to help the researchers. Also, the detailed description of the process in EZR software provided in this paper will help to generate the ROC curve easily.

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