Receiver Operator Characteristic (ROC) curves

Receiver operator characteristic (ROC) curves are a way of graphically displaying the diagnostic performance of a given test. In a ROC curve the sensitivity of the test is plotted over the entire range of possible specificities.

Sensitivity is the proportion of cases with a disease and with a positive test result. Specificity is the proportion of cases without the disease and with a negative test result.

For example the prostate specific antigen (PSA) test for prostate cancer has an established cut-off value of 4.0 ng/ml. Patients with a test value below 4.0 are considered to be normal / healthy and those with a PSA score above 4.0 considered to be abnormal or as suspected of having prostate cancer. Clearly there will be patients with PSA values below 4.0 that have cancer (false negative) and those above 4.0 that do NOT have cancer (false positive). A ROC curve allows the relationship between sensitivity and specificity for a given test to be visualised graphically. For example if the cut-off value for PSA was increased to 10 ng/ml there would be fewer false positive cases but less prostate cancer cases detected. This also means that for a given test a cut-off value can be determined that either maximises the sensitivity and specificity or is the most clinically acceptable.

An excellent website is [http://www.anaesthetist.com/mnm/stats/roc/Findex.htm](http://www.anaesthetist.com/mnm/stats/roc/Findex.htm) which allows you to see the effect of changing threshold values on the sensitivity and specificity of tests, and demonstrates how to construct a ROC curve.

Below is a generic ROC curve. The x-axis shows the false positive rate (or 100-specificity), and the y-axis shows the true positive rate (or sensitivity). Each point of the ROC plot depicts a sensitivity/specificity pair for a particular cut-off (threshold) value. As the sensitivity of the test increases, there will usually be a greater proportion of false positive tests. ROC curves are analysed by calculating the Area Under the ROC Curve (AUC); the larger the number the better the diagnostic test. A test with a perfect discrimination has a ROC curve that passes through the upper left-hand corner (i.e. 100% sensitivity and 100% sensitivity) and an AUC = 1. Therefore the closer the curve is to the upper left corner the better a test. A ROC curve that follows the diagonal dashed line (in the below figure) has an AUC = 0.5 (i.e. 50% sensitivity and 50% specificity); that is, the results of the test are no better than that of flipping a coin.

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