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Original Research Article

Integrating physician's and patient's interest before judging the efficiency of a diagnostic test

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ABSTRACT

Background: Customarily, physicians utilize an efficient diagnostic test before confirming the illness to start a treatment procedure. In this process, physician's seeks maximum possible sensitivity and specificity. On the contrary, patient wants maximum attainable positive and negative predictive values. A duality exists between both vital patient's and physician's interest and it helps to judge whether a diagnostic is superior.
Methods: This article integrates physician's and patient's interest in a novel manner to judge a diagnostic test is efficient. This approach is seen to be optimal, according to illustrations.
Results: The results based on expressions of this article in data on rotavirus, mammogram, post-surgery infection, opinion of two independent nurses about ear infection, whether a surgery contained cancer cells, whether a second surgery rectifies ruptures in breast gels, and whether the elder's fall due to medications they consumed are all convincing that the integration works well.
Conclusions: The new integrated metric, $\Im_{combined,index}$, susceptibility index, excessive risk, calibration index, and phi-coefficients of this article are supportive to that both the physician's and patient's interest together identify a superior diagnostic test.

Keywords: Positive and negative Predictive Values, Prevalence, Sensitivity, Specificity, Shanmugam, Metrics Youden versus

INTRODUCTION

A diagnostic test is a precursor before selecting a treatment for an illness such as breast or colon cancer, diabetic, heart illness. The Pap smear is a diagnostic screening procedure before treating the cervical dysplasia. The cervical dysplasia is an abnormal growth of cells on the surface of the cervix that could lead to cancer. The electrocardiogram records electrical activity of the heart and it helps before a treatment begins. Mammography helps to select a treatment for breast cancer. The measurement of antigen, PSA in the blood helps before treating the prostate cancer. The measurement of the central corneal thickness (CCT) helps before treating glaucoma, an eye illness which can even cause vision loss.

Such diagnostic tests need to be efficient from both the physician's and patient's interest. Currently one interest without the other is practiced and it makes the process of selecting the best diagnostic is incomplete. This article rectifies the deficiency.

The details do follow now. The physician's interest focuses on getting a high proportion of positive result from those with the illness and equally a high proportion of negative result from the healthy participants. The patient's interest focuses on noticing the illness once the participants obtained positive test result and being actually healthy once they received negative test result. The physician's focal and conditional are reversed when it comes to the patient's counterparts. Shouldn't an acceptable approach to judge the efficiency of a diagnostic test based on both interests? What are such metrics that are employed to serve the interest of each? What are their dual intricacies? How could they be integrated? These and other pertinent research questions are addressed in this article. First, authors collect the concepts and expressions from the literature and examine their merits/short-comings as they are done in the next section.

This article offers an acceptable resolution. In Section 2, the literature is reviewed to collect the metrics that are used to judge the efficiency of a diagnostic test. In Section 3, new metrics are derived, and discussed. In Section 4, the expressions are illustrated using data on rotavirus among children who vomited, mammogram result women, post-surgery infection, what two nurses thought independently about infection, whether a surgery controlled cancer cells, whether a second surgery rectified ruptures from transplanted breast gels, and whether the elder's fall due to medications they consumed.

METHODS

A diagnostic test ought to be assessed for the patient's and physician's benefits. Otherwise, a diagnostic might be incomplete dissatisfying one of the two constituencies. A research question is then how both constitutional interests need to be integrated. The physician wants maximum sensitivity (S_e) and maximum specificity (S_p). The sensitivity is the probability, $\Pr(+|D)$ of obtaining positive test result among those ill D. The specificity is the probability $\Pr(-|\bar{D})$ of getting negative test among those healthy $\bar{D}$. The incidences D and $\bar{D}$ are mutually exclusive. The proportions πS_e and $(1-\pi)S_p$ are called true positive and true negative, where $\pi = \Pr(D)$ is the prevalence level of an illness. The proportions $(1-\pi)(1-S_p)$ and $(1-\pi)S_p$ are called false positive and false negatives (Table 1).

Not everyone with a positive result (+) is necessarily ill. This idea is called Positive Predictive Value (PPV). Likewise, not everyone with a negative result (-) is healthy without the illness. This is referred Negative Predictive Value (NPV). Symbolically, these are $PPV = \Pr(D|+)$ and $NPV = \Pr(\bar{D}|-)$. Is a diagnostic test efficient by the patient? The patients expects a high value for both PPV and NPV (Table 2).

Table 1: A Summary of physician's interest.

$True \rightarrow$ $Result \downarrow$	D	$\bar{D}$	Marginal
$(+)$	πS_e	$(1-\pi)(1-S_p)$	$1-S_p+\pi\Im_{Youden}$
$(-)$	$\pi(1-S_e)$	$(1-\pi)S_p$	$S_e-\pi\Im_{Youden}$
Marginal	$\pi = \Pr(D)$	$1-\pi = \Pr(\bar{D})$	1

Table 2: A Summary of dual patient's interest.

$Got \rightarrow$ $wonder \downarrow$	$(+)$	$(-)$	Sum
D	$(1-S_p+\pi\Im_{Youden})PPV$	$(S_p-\pi\Im_{Youden})(1-NPV)$	$PPV+\Im_{Shanmugam}(\pi\Im_{Youden}-S_p)$
$\bar{D}$	$(1-S_p+\pi\Im_{Youden})(1-PPV)$	$(S_p-\pi\Im_{Youden})NPV$	$1-PPV-\Im_{Shanmugam}(\pi\Im_{Youden}-S_p)$
Sum	$(1-S_p+\pi\Im_{Youden})$	$(S_p-\pi\Im_{Youden})$	1

The well-known Youden metric,

$$\Im_{Youden} = S_e + S_p - 1 \quad (1)$$

declares a diagnostic test superior, when its value is closer to one, from the physician's viewpoint. The $\Im_{Youden}$ is $y-$ coordinate minus coordinate on a locus of the Receiver Operating Characteristic (ROC) curve. The metric $\Im_{Youden}$ does not reveal whether the test has high sensitivity or high specificity. A negative value of $\Im_{Youden}$ means an inferior diagnostic test.

An alternate metric was devised by Shanmugam.[1] It is;

$\Im_{Shanmugam} = PPV + NPV - 1$ (2) to refer the superiority of a diagnostic test from the patient's perspective. There is a duality between $\Im_{Youden}$ and $\Im_{Shanmugam}$. A negative (positive) value of $\Im_{Shanmugam}$ means an inferior (superior) diagnostic test from the patient's point of view.

Suggested new method

In this section, authors develop new metrics and discuss their relevance. From the physician's perspective, the positive and negative excess risk ratios $\Im^{+}_{excessRisk,Youden}$ and $\Im^{-}_{excessRisk,Youden}$ connect the prevalence, sensitivity and specificity according to Shanmugam.[2] That is

$$\Im^{+}_{excessRisk,Youden} = 1 - \frac{(1-\pi)(1-S_p)}{\pi S_e} \quad (3)$$

A visual mosaic masonry as an alternate to ROC was constructed by Shanmugam.[3] The mosaic tile areas

$$\Im_{tileArea,Youden} = S_e S_p \quad (4)$$

and

$$\Im^{-}_{tileexcessRisk,Youden} = 1 - \frac{\pi(1-S_e)}{(1-\pi)S_p} \quad (5)$$

reflect the efficiency and excessive risk. Likewise, the positive and negative predictive excessive risk and capture from patient's perspective, according to Shanmugam.[2] They are:

$$\Im^{+}_{excessRisk,Shanmugam} = 1 - \frac{(S_p - \pi\Im_{Youden})(1-NPV)}{(1-S_p+\pi\Im_{Youden})PPV} \quad (6)$$

and

$$\Im^{-}_{excessRisk,Shanmugam} = 1 - \frac{(1-S_p+\pi\Im_{Youden})(1-PPV)}{(S_p-\pi\Im_{Youden})NPV}. \quad (7)$$

Unless both positive and negative predictive values are large, the tile area, $\Im_{tileArea,Shanmugam}$ is not large. The alternate mosaic tile area

$$\Im_{tileArea,Shanmugam} = (PPV)(NPV) \quad (8)$$

is large from the patient's perspective.

The positive or negative predictive calibration metrics reveal whether the diagnostic test needs a calibration. Such metrics in (9) and (10) are:

$$\Im^{+}_{calbration,Shanmugam} = \frac{\pi}{\Im_{Shanmugam} + 1 - NPV} \quad (9)$$

and

$$\Im^{-}_{calbration,Shanmugam} = \frac{(1-\pi)}{\Im_{Shanmugam} + 1 - PPV}. \quad (10)$$

The calibration metrics are small when $\Im_{Shanmugam}$ is large. In duality, the sensitivity and specificity calibration metrics exist from the physician's interest viewpoint. Such metrics in (11) and (12) are:

$$\Im^{+}_{calbration,Youden} = \frac{(1-S_p+\pi\Im_{Youden})}{\Im_{Youden} + 1 - S_p} \quad (11)$$

and

$$\Im^{-}_{calbration,Youden} = \frac{(S_p-\pi\Im_{Youden})}{\Im_{Youden} + 1 - S_e} \quad (12)$$

These calibration metrics are small when the metric $\Im_{Youden}$ is large. By matching the dual calibration metrics in (11) and (12) respectively with those in (9) and (10), authors obtain the Theorem 1 and Theorem 2.

Theorem 1. Note that;

$$(1-S_p+\pi\Im_{Youden})(\Im_{Shanmugam} + 1 - NPV) = \pi(\Im_{Youden} + 1 - S_p)$$

because $\Im^{+}_{calbration,Shanmugam} = \Im^{+}_{calbration,Youden}$

Theorem 2. Note that,

$$(1-\pi)(\Im_{Youden} + 1 - S_e) = (S_p - \pi\Im_{Youden})(\Im_{Shanmugam} + 1 - PPV)$$

because $\Im^{-}_{calbration,Shanmugam} = \Im^{-}_{calbration,Youden}$

The positive susceptibility metric in (13) captures the extra proportion susceptible to illness and it increases when $\Im^{+}_{calbration,Shanmugam}$ is large and/or π is small. The negative susceptibility metric in (14) displays the extra proportion to show additional healthy individuals and it increases when the metric $\Im^{-}_{calbration,Shanmugam}$ is large

and/or $(1-\pi)$ is small. The positive and negative susceptibility metrics are:

$$\Im^{+}_{suceptibility,Shanmugam} = \frac{\Im_{Shanmugam}\Im^{+}_{calbration,Shanmugam}}{\pi} \quad (13)$$

and

$$\Im^{-}_{suceptibility,Shanmugam} = \frac{\Im_{Shanmugam}\Im^{-}_{calbration,Shanmugam}}{(1-\pi)}. \quad (14)$$

From the physician's perspective, the sensitivity based susceptibility metric in (15) captures the extra proportion susceptible to get positive result and it increases when the metric $\Im^{+}_{calbration,Youden}$ is large and/or $(1-S_p+\pi\Im_{Youden})$ is small. Likewise, the specificity based susceptibility metric in (16) displays the extra proportion likely to get negative result and it increases when is $\Im^{-}_{calbration,Youden}$ large and/or $(S_p-\pi\Im_{Youden})$ is small. The positive and negative susceptibility metrics, from the physician's interest, are

$$\Im^{+}_{suceptibility,Youden} = \frac{\Im_{Youden}\Im^{+}_{calbration,Youden}}{(1-S_p+\pi\Im_{Youden})} \quad (15)$$

and

$$\Im^{-}_{suceptibility,Youden} = \frac{\Im_{Youden}\Im^{-}_{calbration,Youden}}{(S_p-\pi\Im_{Youden})}. \quad (16)$$

An intrinsic consequence of the duality between the physician's and patient's perspectives is in balancing equation (17). This balancing equation was derived, using a different principle called a double anchor relation, by Shanmugam1 and it is:

$$\pi(1-\pi)\Im_{Youden} = [1-S_p+\pi\Im_{Youden}][S_e-\pi\Im_{Youden}]\Im_{Shanmugam} \quad (17)$$

The odds for a diagnostic test to be superior, from the physician's interest point of view, is;

$$\Im_{odds,Youden} = [(\Im_{tileArea,Youden})^{-1}-1]^{-1} \quad (18)$$

which increases when the mosaic tile area increases. This is "gold standard" by the physician. The odds ratio,

$$\Im_{oddsRatio,Youden} = [1-\frac{\Im_{Youden}}{\Im_{tileArea,Youden}}]^{-1}. \quad (19)$$

is an association between the test results and the illness by the physician's perspective. In duality, from the patient's interest, the odds for a diagnostic test to be superior is;

$$\Im_{odds,Shanmugam} = [(\Im_{tileArea,Shanmugam})^{-1}-1]^{-1} \quad (20)$$

which increases when the alternate mosaic tile area $\Im_{tileArea,Shanmugam}$ increases. The odds ratio,

$$\Im_{oddsRatio,Shanmugam} = [1-\frac{\Im_{Shanmugam}}{\Im_{tileArea,Shanmugam}}]^{-1}. \quad (21)$$

is another metric of the association between the test results and the state of the illness from the patient's perspective. A comparison of the dual metrics in (21) and (19), authors obtain the Theorem 3.

Theorem 3. Note that,

$$\Im_{tileArea,Youden}(\Im_{tileArea,Shanmugam}-\Im_{Shanmugam}) = \Im_{tileArea,Shanmugam}(\Im_{tileArea,Youden}-\Im_{Youden})$$

The Phi-coefficient in (22) from the physician's perspective is a correlation between the test results and the illness.

$$\Im_{phi-coefficient,Youden} = \Im_{tileArea,Youden}\sqrt{\frac{\pi(1-\pi)}{\{[1-S_p+\Im_{Youden}\pi)].[S_e-\Im_{Youden}\pi]\}}} \quad (22)$$

The metric $\Im_{phi-coefficient,Youden}$ is larger when the mosaic tile area $\Im_{tileArea,Youden}$ becomes larger. An alternate metric from the patient's perspective is (23), which becomes larger when the mosaic metric $\Im_{tileArea,Shanmugam}$ becomes larger.

$$\Im_{phi-coefficient,Shanmugam} = \Im_{tileArea,Shanmugam}\sqrt{\frac{(S_p-\pi\Im_{Youden})}{(1-S_p+\pi\Im_{Youden})}\cdot\frac{}{[1-PPV-(\pi\Im_{Youden}-S_p)\Im_{Shanmugam}]}\cdot\frac{}{[PPV+\pi\Im_{Youden}+(\pi\Im_{Youden}-S_p)\Im_{Shanmugam}]}} \quad (23)$$

Having seen a duality between the physician's and patient's perspectives, authors wonder whether a crossbreeding is feasible and advantageous. One such crossbreed metric to identify a superior diagnostic test could be,

$$\Im_{crossBreed} = (\Im_{tileArea,Youden} - \Im_{Youden}) + (\Im_{tileArea,Shanmugam} - \Im_{Shanmugam}) + [S_p NPV + S_e PPV - 1] \quad (24)$$

Unless all (S_e, S_p, PPV, NPV) are higher, the metric $\Im_{crossBreed}$ does not name a diagnostic test superior and it is better than the individual metrics $\Im_{Youden}$ and $\Im_{Shanmugam}$. A factor reflects an equilibrium between the physician's and patient's perspective, and it is $\Im_{equilibrium} = [S_p NPV + S_e PPV - 1]$. Another cross breed metric is odds based and it is

$$\Im_{crossBreed,odds} = [(S_p + PPV - 1)^{-1}(S_e + NPV - 1)^{-1} - 1]^{-1} \quad (25)$$

which identifies a superior diagnostic test.

A duality between metrics $\Im_{Youden}$ and $\Im_{Shanmugam}$ was identified using double anchor weights by Shanmugam.[1] They are:

$$\Im_{anchorWeight1} = \pi(1-\pi)\Im_{Youden} \quad (26)$$

and

$$\Im_{anchorWeight2} = [(1-S_p) + \Im_{Youden}\pi)] [S_e - \Im_{Youden}\pi]\Im_{Shanmugam} \quad (27)$$

Using the anchor weights, a principle of authentication was constructed earlier to distinguish a strong from a circumstantial evidence by Shanmugam.[1] When both anchors weigh the same amount, a diagnostic test is considered balanced between the physician's and patient's perspectives. Otherwise, there exists an imbalance as measured by:

$$\Im_{imbalance} = \Im_{anchorWeight1} - \Im_{anchorWeight2}. \quad (28)$$

When the imbalance is positive (negative), the diagnostic test is favorable to the physician's (patient's) interest. Their total

$$\Im_{total} = \Im_{anchorWeight1} + \Im_{anchorWeight2} \quad (29)$$

is always positive.

The maximum attainable anchor weight is a quadratic function of the prevalence, $0 < \pi < 1$. By differentiating with respect to and equating to zero, it yields the critical value π_c. authors check whether the critical value makes its second derivative negative. After doing so, authors notice the maximum as:

$$\Im_{\max,anchorWeight1} = \max_{\pi} \Im_{anchorWeight1} = \frac{1}{4}\Im_{Youden} if\ \Im_{Youden} \neq 0 \quad (30)$$

and

$$\Im_{\max,anchorWeight2} = \max_{\pi} \Im_{anchorWeight2} = [(1-S_p) + \frac{\Im_{Youden}}{2})] [S_e - \frac{\Im_{Youden}}{2}]\Im_{Shanmugam}, \quad (31)$$

$$if\ \Im_{Shanmugam} \neq 0.$$

Authors also notice the following relations

$$[PPV - \Im_{Shanmugam} S_p] = [1 - \{1 + \Im_{Shanmugam}\}\Im_{Youden}]\pi, \quad (32)$$

and

$$[PPV - \Im_{Shanmugam} S_p] = [1 - \Im_{Youden}\Im_{Shanmugam}]\pi. \quad (33)$$

Their dual metrics

$$\Im_{combined,Youden} = \frac{\Im_{anchorWeight1}\Im_{tileArea,Youden}}{\Im_{Youden}} \quad (34)$$

and

$$\Im_{combined,Shanmugam} = \frac{\Im_{anchorWeight2}\Im_{tileArea,Shanmugam}}{\Im_{Shanmugam}} \quad (35)$$

Portray respectively the physician's preference with the higher sensitivity and specificity and the patient's preference with higher positive predictive and negative predictive values. A comparison of the dual metrics (34) and (35) reveals the Theorem 4, because $\Im_{anchorWeight1}$ equal to $\Im_{anchorWeight1}$.

Theorem 4. The proportionality between the physician's and patient's interests is:

$$\frac{\Im_{tileArea,Youden}}{\Im_{Youden}} = \frac{\Im_{tileArea,Shanmugam}}{\Im_{Shanmugam}}$$

Furthermore, the dual metrics:

$$\Im_{norm1,Youden} = [1 + \frac{\Im_{anchorWeight1}(\frac{\Im_{area,Youden}}{\Im_{Youden}} - 1)}{2S_e}]^{-1} \quad (36)$$

and

$$\Im_{norm1,Shanmugam} = \frac{\Im_{anchorWeight2}(\frac{\Im_{area,Shanmugam}}{\Im_{Shanmugam}} - 1)}{[1 + \frac{\Im_{anchorWeight2}(\frac{\Im_{area,Shanmugam}}{\Im_{Shanmugam}} - 1)}{2PPV}]^{-1}} \quad (37)$$

Portray the efficiency of a diagnostic test from the physician's and patient's perspective respectively. Also, the dual metrics:

$$\Im_{norm2.Youden} = \frac{\Im_{Youden}}{[1 - S_p + \pi\Im_{Youden}][S_p - \pi\Im_{Youden}]} \quad (38)$$

and

$$\Im_{norm2.Shanmugam} = \frac{\Im_{Shanmugam}}{\pi(1-\pi)} \quad (39)$$

Indicates the efficiency of a diagnostic from the physician's and patient's interest point of view. Due to the proportionality in Theorem 4, authors note that $\Im_{norm2.Shanmugam} = \Im_{norm2.Youden}$. Having seen two parallel tracks (one from the physician's interest and another from the patient's interest) to judge the efficiency of a diagnostic test, authors may integrate every pair of the above derived dual result as follows.

$$\Im_{combined} = \frac{1 - e^{-(\Im_{YoudenType} + \Im_{ShanmugamType})}}{1 + e^{-(\Im_{YoudenType} + \Im_{ShanmugamType})}} \quad (40)$$

and the diagnostic test is superior (inferior) if the metric $\Im_{combined}$ is higher (smaller). Such a metric accommodates both the physician's and patient's interest.

For an example, authors integrate the Youden's and Shanmugam's metrics in (1) and (2) respectively into single combined metric which satisfies both the physician's and patient's interests.

$$\Im_{combined,metric} = \begin{cases} \min\{\frac{(\Im_{Youden} + \Im_{Shanmugam})}{[1 + (\Im_{Youden} + \Im_{Shanmugam})]}, 1\} \\ \max\{\frac{(\Im_{Youden} + \Im_{Shanmugam})}{[1 - (\Im_{Youden} + \Im_{Shanmugam})]}, -1\} \end{cases} \quad (41)$$

$$if \begin{cases} \Im_{Youden} + \Im_{Shanmugam} > 0 \\ \Im_{Youden} + \Im_{Shanmugam} < 0 \end{cases}$$

A simple comparison between the combined metric in (41) with the Youden's metric in (1) and Shanmugam's metric in (2) reveals that the combined metric in (41) outperforms both individually.

RESULTS

In this section, authors illustrate mentioned concepts and expressions (1) through (41) using data from different scenarios and disciplines.

The data in (Table 3) describes the presence or absence of rotavirus among a random sample of n = 393 children who vomited as in Taube.[4] The vomiting is a diagnostic symptom. The prevalence rate, $\pi = 0.43$ of rotavirus is a moderate value, but the proportion, $1 - S_p + \pi\Im_{Youden} = 0.70$ of vomiting is a high value. Hence, there is a mismatch between the two proportions. The sensitivity, $S_e = 0.87$ is a high value with a low specificity, $S_p = 0.42$. The patients with rotavirus are likely to vomit but healthy persons without rotavirus are less likely not to vomit. The negative predictive value, $NPV = 0.81$ is high with a moderate positive predictive value $PPV = 0.53$. It means that only a moderate proportion of those who vomit is likely to have rotavirus. On the contrary, a high proportion of those who do not vomit is likely to be healthy without rotavirus. The Youden and Shanmugam tile area $\Im_{tileArea,Youden} = 0.37$ and $\Im_{tileArea,Youden} = 0.43$ are moderate (less than 50%) meaning that vomiting is a reasonable precursor for rotavirus and vice versa. The Youden's negative $\Im^{-}_{excessiveRisk,Youden} = 0.76$ and Shanmugam's positive excessive risk $\Im^{+}_{excessiveRisk,Shanmugam} = 0.85$ are high meaning that Youden's metric connects the prevalence more with specificity and Shanmugam's metric connects the prevalence more with sensitivity. Because the metric, $\Im^{+}_{susceptibility,Shanmugam} = 0.65$ there is a high chance for the extra proportion to show rotavirus in repeated examination of vomiting and rotavirus. On the contrary, because the metric $\Im^{-}_{susceptibility,Youden} = 0.69$ is high, there is a high chance for the extra proportion likely to show no rotavirus illness. The odds of Shanmugam is high $\Im_{odds,Shanmugam} = 0.75$ but the odds of Youden $\Im_{odds,Youden} = 0.58$ is moderate. The correlation metrics $\Im_{phi,Shanmugam} = 0.49$ and $\Im_{phi,Youden} = 0.40$ are moderate, reflecting that the relationship between vomiting and rotavirus illness is impressive. The metrics, $\Im_{Youden} = 0.36$ and $\Im_{Shanmugam} = 0.43$ are moderate, meaning that vomiting is a good diagnostic for rotavirus and vice versa. The patient's interest is a bit more satisfied than the physician's interest by the data. An integrated metric is worthwhile. The integrated metric

$\Im_{combined} = 0.39$ is positive and moderate, suggesting that vomiting is a moderate symptom for rotavirus and vice versa satisfying both the physician's and patient's interest.

The mammogram result versus the occurrence of breast cancer in n = 3,000 women in (Table 4) from Zhou et al, are considered.[5] The prevalence level, $\pi = 0.01$ is low but the proportion, $1 - S_p + \pi\Im_{Youden} = 0.64$ with positive test result in the mammogram is a high value. The proportions are not matching, implying that the physician's and patient's interest are divergent. The sensitivity, $S_e = 0.97$ is higher than the specificity, $S_p = 0.37$. It means that many breast cancer patients are likely to get positive result but only a moderate percent of the healthy is likely to get the negative test result in mammogram. The converse reflects nonproportionality, because of the high $NPV = 0.99$ but less $PPV = 0.02$. The positive test result in mammogram is not indicative of acquiring breast cancer. But, the negative result in the mammogram suggests a high confidence of immunity to breast cancer. The Youden tile area $\Im_{tileArea,Youden} = 0.33$ and the Shanmugam tile area $\Im_{tileArea,Shanmugam} = 0.02$ suggest that the physician's interest is better satisfied than the patient's interest. Both the Youden's negative $\Im^{-}_{excessiveRisk,Youden} = 0.99$ and Shanmugam's positive excessive risk $\Im^{+}_{excessiveRisk,Shanmugam} = 0.96$ are high meaning that Youden's metric connects the prevalence with specificity and Shanmugam's metric connects the prevalence with sensitivity. Because $\Im^{+}_{susceptibility,Shanmugam} = 0.94$, there is a high chance for the extra proportion to show breast cancer in future. On the contrary, because $\Im^{-}_{susceptibility,Youden} = 0.91$, there is a high chance for extra proportion to show no breast cancer also. Not the odds $\Im_{odds,Shanmugam} = 0.01$ but the odds $\Im_{odds,Youden} = 0.54$ is high, suggesting that more women are healthy, while more get positive mammogram result. The correlation, $\Im_{phi,Shanmugam} = 0.81$ but not $\Im_{phi,Youden} = 0.07$ is high, reflecting that the relationship between mammogram and breast cancer is impressive from patient's, not so from the physician's perspective. The metric $\Im_{Youden} = 0.33$ is moderate but the metric $\Im_{Shanmugam} = 0.01$ is low, suggesting that the patient's and physician's interest are unevenly satisfied. The integrated metric $\Im_{combined} = 0.26$ is low, suggesting that mammogram test result is not that good a diagnostic for breast cancer.

Would an infection occur after surgery, according to MRI result in a sample of n = 39 men in a hospital at Austin as reported by Shanmugam.[3] See the data in (Table 5). The prevalence level $\pi = 0.62$ of surgical infection is high in par with those received positive test result in the MRI $1 - S_p + \pi\Im_{Youden} = 0.62$, implying there is an equilibrium between the patient's and physician's interest. The sensitivity, $S_e = 0.83$ and specificity, $S_p = 0.73$ are high, meaning that patients who had surgery are likely to get positive result for surgical infection in MRI test. The patients without surgical infectivity are likely to get negative result in the MRI test. Likewise, the negative predictive value $NPV = 0.83$ and positive predictive value $PPV = 0.73$ are high, suggesting that those with positive test result in MRI will have surgical infectivity and those with the negative result are immune to the surgical infectivity. The Youden and the Shanmugam tile areas are in equilibrium and equal to $\Im_{tileArea,Youden} = 0.61 = \Im_{tileArea,Shanmugam}$ meaning that the physician's interest and the patient's interest are equally satisfied. This example echoes an existence of a parity among the physician's and patient's interest. The parity metrics $\Im^{+}_{excessiveRisk,Youden} = 0.80$ and $\Im^{+}_{excessiveRisk,Shanmugam} = 0.80$ are high meaning that they connect prevalence with the sensitivity. The metrics $\Im^{-}_{susceptibility,Shanmugam} = 1.08$ and $\Im^{-}_{susceptibility,Youden} = 0.77$ are high, meaning that there is a high chance for extra proportion to show surgical infectivity from the perspectives of both physician's and patient's perspective. The odds for susceptibility metrics $\Im_{odds,Shanmugam} = 1.57 = \Im_{odds,Youden}$ are high, meaning that more get positive MRI result as more people have surgical infectivity. The correlation metrics, $\Im_{phi,Shanmugam} = 0.61$ and $\Im_{phi,Youden} = 0.61$ are high, reflecting that the relationship between the MRI result and surgical infectivity is impressive from the physician's and patient's perspective. The metrics $\Im_{Youden} = 0.57 = \Im_{Shanmugam}$ are moderate and equal, indicating that the MRI is a reasonable diagnostic for surgery infection from both the patient's and physician's interest. The integrated metric $\Im_{combined} = 0.53$ is high, confirming that the MRI result is also good for the existence of surgical infectivity.

Two nurses' opinion on tympanic membrane in the eardrum of a sample of n = 100 patients with ear infection as displayed in (Table 6) from Le.[6] The prevalence level of the ear infection, $\pi = 0.45$ is a moderate value but the chance $1 - S_p + \pi\Im_{Youden} = 0.55$

for confirmation by the nurse 2 is also high, implying there is a slight nonequilibrium between the nurses. The sensitivity, $S_e = 0.78$ and specificity, $S_p = 0.64$ are high. The negative predictive value $NPV = 0.78$ and positive predictive value $PPV = 0.67$ are high, pointing out a harmony among the nurses. Both metrics $\Im_{tileArea,Youden} = 0.49 = \Im_{tileArea,Shanmugam}$ are moderate and equal, meaning that both nurse's diagnostics are equally the same. The metrics $\Im^{+}_{excessiveRisk,Youden} = 0.43$ and $\Im^{+}_{excessiveRisk,Shanmugam} = 0.71$ are high, meaning that they connect the prevalence with the nurse's diagnostic. Likewise, the susceptibility metrics $\Im^{+}_{susceptibility,Shanmugam} = 0.65$ and $\Im^{+}_{susceptibility,Youden} = 0.53$ are high, meaning there is a high chance for the extra proportion for tympanic membrane infection. The odds for susceptibility are equally high since $\Im_{odds,Shanmugam} = 0.98 = \Im_{odds,Youden}$. The correlations $\Im_{phi,Shanmugam} = 0.49$ and $\Im_{phi,Youden} = 0.48$ are high, reflecting that there is an agreement among the nurses. The metrics $\Im_{Youden} = 0.41 = \Im_{Shanmugam}$ are moderate and equal. Consequently, the integrated metric $\Im_{combined} = 0.45$ is moderate, suggesting that the nurses' opinions are harmonious.

Would a surgery control proliferating cancer cells, according to reproduced data in (Table 7) from Agresti.[7] The prevalence level $\pi = 0.12$ cancer cell is a low but the proportion recovered from cancer $1 - S_p + \pi\Im_{Youden} = 0.56$ is a high value, pointing out that there is a mismatch between cancer removal and surgery. The sensitivity $S_e = 0.41$ and specificity $S_p = 0.41$ are in parity, those underwent surgery are likely to have cancer removal in par with those who did not undergo surgery to have cancer removal. The negative predictive value, $NPV = 0.83$ and the positive predictive value, $PPV = 0.08$ are not matching, suggesting that the proportion to have surgery is not in par with the proportion to have no surgery for cancer removal. Neither the metric $\Im_{tileArea,Youden} = 0.17$ nor the metric $\Im_{tileArea,Shanmugam} = 0.07$ is much, meaning that the surgery versus removal of cancer are not relating to each other. The metric $\Im^{-}_{excessiveRisk,Youden} = 0.80$ is high but the positive excessive risk $\Im^{+}_{excessiveRisk,Shanmugam} - 0.5$ and the negative excessive risk $\Im^{-}_{excessiveRisk,Shanmugam} - 0.4$ are negative and low, meaning that the prevalence is connected with specificity well but not with sensitivity. The surgery is perhaps an inferior way to the removal of cancer cell. Neither the odds $\Im_{odds,Shanmugam} = 0.2$ nor $\Im_{odds,Shanmugam} = 0.08$ is high enough, meaning that the odds for surgery or cancer removal is disproportional. The correlation $\Im_{phi,Shanmugam} = 0.31$ is high but not the correlation $\Im_{phi,Youden} = 0.11$, reflecting that the relationship between surgery and cancer removal is one directional but not both directional. The metric, $\Im_{Youden} = -0.18$ is negative and low and the metric, $\Im_{Shanmugam} = -0.08$ is negative, too low, confirming that the surgery is an inferior approach to the removal of cancer. The integrated metric, $\Im_{combined} = -0.35$ is low and negative, suggesting that surgery is an inferior precursor to the cancer removal.

Table 8 contain data of 165 women with breast implants who reported ruptures for a revised surgery to stop ruptures, as reported by Brown et al.[8] The prevalence level, of ruptures is moderate but the proportion underwent surgery to stop rupture, $1 - S_p + \pi\Im_{Youden} = 0.56$ is also high, pointing out that there ought to have been a surplus proportion undergoing surgery. The sensitivity, $S_e = 0.07$ is low but the specificity $S_p = 0.31$ is moderate, meaning that only a less proportion underwent revision surgery among those had reported ruptures, while a significant proportion did not undergo revision surgery among those who had not reported breast transplant rupture. The negative predictive value, $NPV = 0.29$ is moderate but the positive predictive value, $PPV = 0.07$ is non-matching low, suggesting that a less proportion has really reported rupture among those underwent revision surgery whereas there is a moderate proportion did not report rupture among those who did not undergo revision surgery. The metric, $\Im_{tileArea,Youden} = 0.21$ is low in par with metric, $\Im_{tileArea,Shanmugam} = 0.21$, meaning that the revision surgery and reported rupture relate to each other moderately. The positive and negative excessive metrics respectively $\Im^{+}_{excessiveRisk,Youden} = -11.6$ and $\Im^{-}_{excessiveRisk,Youden} = -1.46$ are negative as much as positive excessive risk $\Im^{+}_{excessiveRisk,Shanmugam} - 12.8$ and negative excessive risk, $\Im^{-}_{excessiveRisk,Shanmugam} - 1.25$ meaning that metrics do not connect the prevalence with sensitivity or specificity. The revision surgery is an inferior approach to stop rupture. Neither the odds $\Im_{odds,Shanmugam} = 0.02$ nor $\Im_{odds,Shanmugam} = 0.02$ is too

low, meaning that the odds for revision surgery or for reported ruptures is disproportional. The correlation $\Im_{phi,Shanmugam} = 0.04$ is high but not the correlation $\Im_{phi,Youden} = 0.02$, meaning that there is an insignificant relationship between revision surgery and reported ruptures. The metrics, $\Im_{Youden} = -0.62$ and $\Im_{Shanmugam} = -0.64$ are negative but moderate, implying that the revision surgery and reported ruptures are inferior diagnostic of each other. The integrated metric, $\Im_{combined} = -1.00$ is negative, suggesting that revision surgery is an inferior precursor to further ruptures.

Table 9 contains data about the prevalence and the risk factors for falling among 173 elders in Brazil as reported by Vieira et al.[9] A factor for the elder's falling is thought to be the sedation due to medications they consume. The prevalence level, for elders falling is moderate but the proportion with sedation, $1 - S_p + \pi\Im_{Youden} = 0.78$ is high, pointing out that there is a surplus proportion having sedation. The sensitivity, $S_e = 0.79$ is high but the specificity, $S_p = 0.24$ is moderate, meaning that there is a high proportion with sedation due to medicine among those reported falling, while there is only a moderate proportion without sedation among the reported falling elders. The negative predictive value, $NPV = 0.51$ and the positive predictive value, $PPV = 0.52$ are moderate, suggesting that if an elder has sedative effect, there a moderate chance for the elder to fall as much as if there is an elder without a sedative effect, there is moderate chance for that elder not to fall. The metric, $\Im_{tileArea,Youden} = 0.19$ is reasonable but the metric, $\Im_{tileArea,Shanmugam} = 0.27$ is a bit more, meaning that the sedation versus the reported elders falling relate to each other moderately. The positive and negative excessive metrics respectively $\Im^{+}_{excessiveRisk,Youden} = 0.09$ and $\Im^{-}_{excessiveRisk,Youden} = 0.05$ are less compared to positive excessive risk $\Im^{+}_{excessiveRisk,Shanmugam} = 0.73$ and negative excessive risk $\Im^{-}_{excessiveRisk,Shanmugam} - 2.25$, meaning that Youden's metrics but not the Shanmugam's metrics connect the prevalence well with sensitivity. The sedative effect is not a significant clue for elder's falling. The odds $\Im_{odds,Shanmugam} = 0.37$ and $\Im_{odds,Shanmugam} = 0.23$ are reasonable, meaning that the odds for sedative effect due to medicine or for elders falling is proportional. The correlations $\Im_{phi,Shanmugam} = 0.22$ and $\Im_{phi,Youden} = 0.22$ are moderate and equal, meaning that there is a reasonable relationship between sedative side effect of medicine and the elders falling. The metrics, $\Im_{Youden} = 0.25$ and $\Im_{Shanmugam} = 0.35$ are moderate, confirming a reasonable relation between sedative side effect due to medicine and the elders falling. The integrated metric, $\Im_{combined} = 0.06$ is low, suggesting that the relation between the sedative side effect of medicine and the elders falling is downplayed

DISCUSSION

The contents of this article help to identify the best diagnostic test in any collection of such type. More often than not, medical or healthcare researchers want to select a superior diagnostic test to gather evidences in terms of covariates for such a diagnostic test to function successfully as the best.

For an example, let us consider the diagnosis of cardiovascular illness which involves heart or blood vessels. It includes coronary artery diseases, myocardial infarction, heart failure, hypertensive disease, artery problems, cardiomyopathy, abnormal heart rhythms, congenital heart disease, valvular disease, carditis, thromboembolic disease, rheumatic, venous thrombosis, and aneurysms.[10] To select the best among several diagnostics, the medical history of the patient might be useful because the heart problems often produce some symptoms, such as palpitations and sensations of extra or missing heart beats etc. Among a variety of blood tests that are available for C-reactive protein, blood sugar, lipoprotein homocysteine, cholesterol transport, triglycerides, etc. to assess the evolution of coronary artery disease and evidence of existing damage, the cost could be a factor by the patients. The least costly is the diagnosis of C-reactive protein and maximum costly diagnosis is the diagnosis of coronary calcium scan.[11] Because the causes of cardiovascular disease in a person vary from one to several and they include heart or blood vessel functioning which are disturbed by blood pressure, smoking, diabetes mellitus, lack of exercise, obesity, high blood cholesterol, poor diet, and excessive alcohol consumption, among others. A regression methodology is essential to make a prediction of an episode in future for any patient with diagnostic results.[12]

Recent research trends for making future prediction any event based on diagnostic test results rest on suitable regression methodologies.[13] The regression methodology enables patients to become better informed about their diagnosed test results to encourage them to seek an excellent professional healthcare at an earlier stage in the appropriate situations and risks.[14] Varieties of data mining techniques for the prediction of heart diseases have been considered with the varying level of success and accuracy but none has involved diagnostic test results such as sensitivity, specificity, positive and negative predictive values.[15] The state-of-the-art of the machine learning methodologies have also been applied for the

assessment of heart failure, predicting the events, such as destabilizations, re-hospitalizations, and mortality.[16]

However, accuracy of the multiple linear regression, data mining, and machine learning methodologies could have been enhanced significantly to predict the chance of heart disease more precisely with a proper utilization of the analytic expressions and contents of this article. A software could be easily developed based on such regression methodologies.

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