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Research Article

An assessment of nurses' sufficient immunity when treating infectious patients using bumped-up binomial model

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ABSTRACT

Background: In times of an outbreak of a contagious deadly epidemic[1-4] such as severe acute respiratory syndrome (SARS), the patients are quarantined and rushed to an emergency department of a hospital for treatment. Paradoxically, the nurses who treat them to become healthy get infected in spite of the nurses' precautionary defensive alertness. This is so unfortunate because the nurses might not have been in close contact with the virus otherwise in their life. The nurses' sufficient immunity level is a key factor to avert hospital site infection. Is it possible to quantify informatics about the nurses' immunity from the virus?
Methods: The above question is answered with a development of an appropriate new model and methodology. This new frequency trend is named Bumped-up Binomial Distribution (BBD). Several useful properties of the BBD are derived, applied, and explained using SARS data[5] in the literature. Though SARS data are considered in the illustration, the contents of the article are versatile enough to analyze and interpret data from other contagious diseases.
Results: With the help of BBD (3) and the Toronto data in Table 1, we have identified the informatics about the attending nurses' sufficient immunity level. There were 32 nurses providing 16 patient care services. Though the nurses were precautionary to avoid infection, not all of them were immune to infection in those activities. Using the new methodology of this article, their sufficient immunity level is estimated to be only 0.25 in a scale of zero to one with a p-value of 0.001. It suggests that the nurses' sufficient immunity level is statistically significant. The power of accepting the true alternative hypothesis of 0.50 immunity level, if it occurs, is calculated to be 0.948 in a scale of zero to one. It suggests that the methodology is powerful.
Conclusions: The estimate of nurse's sufficient immunity level is a helpful factor for the hospital administrators in the time of making work schedules and assignments of the nurses to highly contagious patients who come in to the emergency or regular wings of the hospital for treatment. When the approach and methodology of this article are applied, it would reduce if not a total elimination of the hospital site infections among the nurses and physicians.

Keywords: Likelihood ratio, Conditional probability, Odds ratio, SARS epidemic, p-value, Statistical power, Prevalence, Hypothesis test, Nuisance parameter

INTRODUCTION

Ironically, the nurses who do their best to help the contagious patients free of deadly virus to become healthy absorb the virus themselves in the hospital. This is so unfortunate because the nurses might not have been infected on their own in life otherwise of not treating the patients. This phenomenon is called hospital site infection which is a serious concern to the healthcare professionals. A case in point for discussion is the contagious, deadly disease called severe acute respiratory syndrome (SARS). What is it? The SARS[1-4] is a viral respiratory disease. Some[3] preventive actions need to be considered to be disinfected.

The first SARS case appeared in southern China on 27th November 2002. The SARS patient's symptom are usually flu like fever above 100° Fahrenheit with cough, sore throat etc. Antibiotics are ineffective. Consequently, the SARS patients have to be isolated. Their immune system negatively reacts with what is known as cytokine storm. No known cure or protective vaccine exists for the SARS. About 8,273 humans acquired the SARS virus and 775 among them died in 37 countries, according to the World Health Organization (WHO). A scientist[4] in the Russian Academy of Medical Sciences claimed that the SARS coronavirus is a synthesis of measles and mumps and the SARS virus is not a natural product, but rather must have been manufactured under the laboratory conditions. The SARS disease was spreading mainly by the international travellers from China. China was apologetic for slowness to extinguish the SARS epidemic.

In some airports, the international travellers were quarantined and taken to the emergency department of the hospitals. One such place is the Toronto airport in Canada. The SARS patients were taken to the Toronto General Hospital for treatment and recovery. About n = 32 nurses were engaged to treat the SARS patients and several of them got infected by the SARS virus during their service in the Toronto General hospital.[5] Their data from http://wwwnc.cdc.gov/ are cited in Table 1.

Table 1: # infected among n = 32 nurses who provided care to SARS patients.

Patient care activity	Y	Patient care activity (continues)	Y
Administration of medication	5	Venipuncture	6
Assessment of patient	6	Average, $\bar{y}$ =	4.313
Bathing or patient transfer	7	Variance, s_y^2 =	2.229
Endotracheal aspirate	3	Expression (11), $\hat{\phi}_{mle}$ =	0.252
Insertion of a peripheral	3	Expression (12), $\hat{\pi}_{mle,\hat{\phi}}$ =	0.101
Intubation	3	Special case of Expression (12), $\hat{\pi}_{mle,\phi=0}$ =	0.135
Manipulation of bipap mask	3	Expression (15), p-value =	0.001
Manipulation of commodes	3	Expression (16), statistical power to accept true $\phi = 0.5$ is equal to	0.948
Manipulation of oxygen mask	7	Odds for maintaining zero infection policy when $\phi \neq 0$ is $\frac{\Pr(Y=0 \mid \pi, \phi \neq 0)}{\Pr(Y>0 \mid \pi, \phi \neq 0)} =$	0.009
Mouth or dental care	5	Odds for maintaining zero infection policy when $\phi = 0$ is $\frac{\Pr(Y=0 \mid \pi, \phi = 0)}{\Pr(Y>0 \mid \pi, \phi = 0)} =$	0.034
Nebulizer treatment	3	Informatics on *lack of virility*, $\Pr(\bar{\Re} \mid \bar{H}) =$	0.865
Performing an electrocardiogram	4	$\hat{\Pr}(no\_nurse\_is\_infected) =$	0.033
Radiology procedure	4	*Reserve group proportion*, $\Pr(H \mid \Re) =$	0.280
Suctioning after intubation	4	*Odds ratio*, $e^{-\phi Odds(\pi)}(\frac{e^{\pi}}{e^{\pi}-1}) =$	10.13
Suctioning before intubation	3		

METHODS

Note that the expected number, E (Y) of infected nurses is a group size n times the probability, $0 < \pi < 1$ for any one nurse in the group to be infected during their patient care activities, where Y is a binomial random variable. The hospital site infection is a serious concern to all hospital administrators. In all the patient care activities, the nurses are so well professionally trained to use disinfected gloves, nasal masks etc. as part of the preventive measures to avoid infection from the infectious patients like SARS patients. Still, some nurses get infected. What is the mystery? The nurses probably lack much needed sufficient immunity and it is so latent to be noticed. Their immunity must be the key factor of the mystery. The nurses' immunity level must be assessed, if possible, before assigning them to treat highly contagious patients. How to assess the nurses' immunity is the topic for discussion in this article. Acquiring such knowledge about the nurses' immunity level is helpful for the hospital administrators during their assignment decisions of the nurses for the patient care activities.

Let π is the probability for a nurse to get infected from the contagious patients in the hospital and it is higher than zero. The cases, $\pi = 0$ and $\pi = 1$, are excluded from discussions in this article as they are extremes and not practical. In this line of thinking, let $0 \le \phi < 1$ be the probability for a nurse to possess sufficient immunity to treat contagious patients with virus. Closer the probability, ϕ to zero is interpreted as unsafe for the nurse to be assigned to treat the contagious patients like SARS patients. The case $\phi = 1$ is rare. This article blends the probabilities ϕ and π with a random number, Y of infected nurses to come up with an appropriate underlying model for the collected data.

To be rigorous, let the notations R and H denote the events for a nurse to get "infected" due to the virus from the contagious patients like SARS patients and to possess "sufficient immunity from the virus attack". Suppose their probabilities are P(R) = π and Pr(H) = ϕ. Note their conditional probabilities are Pr(R/H) = 0 and Pr(R/H) = p (because only with no sufficient immunity, there is a finite chance for a nurse to be infected) where $\bar{H}$ denotes the lack of sufficient immunity. The number, Y of infected nurses treating contagious patients like SARS patients is usually assumed to follow a binomial distribution

$$\Pr(Y = y) = \binom{n}{y} p^y (1-p)^{n-y}, \quad y = 0,1,2,...,n, 0 < p < 1. \tag{1}$$

When there is a mix of nurses with and without sufficient immunity in reality, the binomial distribution (1) is insufficient to be an underlying model for Y. Using (1) to analyze the infected nurses' data imposes a bias that no nurse in the group has sufficient immunity. A modification to (1) is warranted to avoid the bias. To modify, we proceed as follows, realizing that the marginal and conditional probabilities to become infected among the nurses are connected via

$$\Pr(\Re) = \Pr(H)\Pr(\Re|H) + \Pr(\bar{H})\Pr(\Re|\bar{H}).$$

That is,

$$\pi = \phi(0) + (1-\phi)p. \tag{2}$$

An interpretation of (2) is the following. The proportion of infected nurses is $\hat{\pi}$ while the proportion of the nurses with lesser than the sufficient immunity is

$$\hat{\Pr}(no\_nurse\_is\_\inf ected) = (\frac{\hat{\phi}}{1-\hat{\phi}})\hat{\pi}$$

where $(\frac{\hat{\phi}}{1-\hat{\phi}})$ is the estimated odds of having sufficient immunity. The binomial model (1) is refined by substituting the triangular relation, $p = \frac{\pi}{1-\phi}$ due to (2).

This means in a scenario in which some nurses operate with lesser than the sufficient immunity, an appropriate underlying model for the number, Y of infected nurses is

$$\Pr(Y = y|\pi,\phi) = \binom{n}{y}(\frac{\pi}{1-\phi})^y(1-\frac{\pi}{1-\phi})^{n-y}, \quad y = 0,1,2,...,n, 0 < \pi < 1-\phi, 0 \le \phi < 1 \tag{3}$$

The model (3) is named a bumped-up binomial distribution (BBD). Given there is no sufficient immunity, the probability for a nurse to be not infected is

$$\Pr(\bar{\Re}|\bar{H}) = (\frac{1-\phi-\pi}{1-\phi}). \tag{4}$$

The probability, (4) portrays lesser virility of the SARS patients. Hence, the proportion, (4) is named probability-informatics about the lack of virility.

When $\phi = 0$, the BBD (3) reduces to the regular binomial distribution (1) as a special case of not sufficient immunity scenario among the nurses. Otherwise, by rewriting the triangular relation as π = (1 - ϕ), a contour of restricted feasibilities for the probability, π to get infected in general, the proportion, p of infected nurses with no sufficient immunity and the probability, ϕ for the existence of sufficient immunity in a nurse. Such restricted feasibilities are sketched in the shaded triangle of Figure 1. With x-axis, y-axis and z-axis denoting respectively the probabilities ϕ, p and π, the dynamics among them are captured in three dimensional plot of Figure 2.

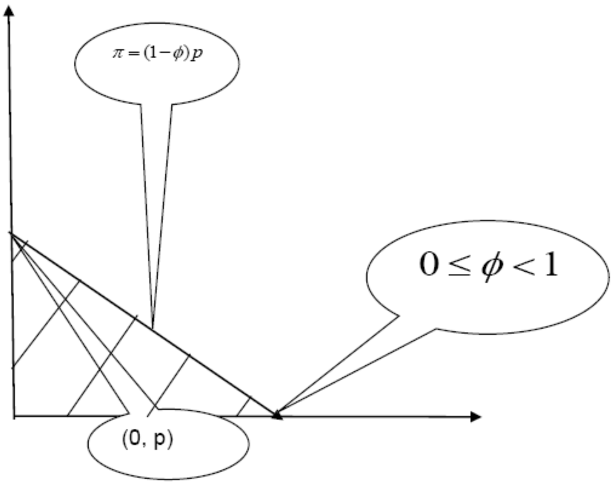

Figure 1: Triangular relation.

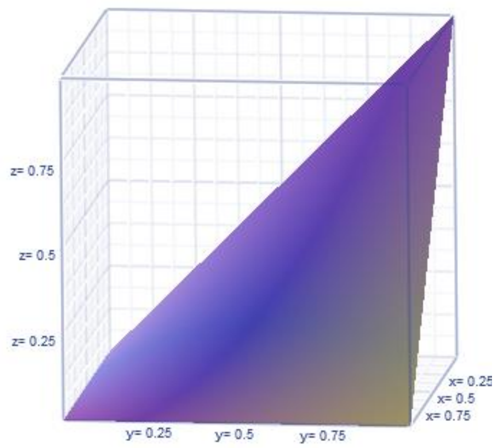

Figure 2: Dynamics among *f*, *p* , and *π*.

There are other intrigues. Given that a nurse is infected, the conditional probability, Pr(R/H) portrays the likelihood for the sufficient immunity to have existed. Such conditional probability must also be zero since $\Pr(H|\Re) = \frac{\phi \Pr(\Re|H)}{\pi} = 0$.

We therefore ask: Could a nurse possess sufficient immunity given that the nurse is not infected? The answer is "yes". If so, what is its probability? Because a nurse is infected with a conditional probability, Pr(R/H) = p only when the nurse has no sufficient immunity, its reverse conditional probability is

$$\Pr(H|\bar{\Re}) = (\frac{\phi}{1-\pi}) . \quad (5)$$

The probability-informatics, (5) portrays the proportion of nurses with sufficient immunity among the nurses not infected. The proportion (5) is named the reserve group proportion of nurses for re-use in the next time to treat contagious patients by the hospital administrators. The odds of possessing sufficient immunity among the nurses not infected are $Odds(H|\bar{\Re}) = (\frac{\phi}{1-\phi})$. However, the expected number, $E(Y|\pi,\phi)$ of the BBD (3) is

$$E(Y|\pi,\phi) = n(\frac{\pi}{1-\phi}) . \quad (6)$$

The expected number, (6) reduces to a smaller number when the proportion of nurses with sufficient immunity is negligible (that is, $\phi \to 0$). In other words, using the usual binomial distribution (1) means incorrectly assuming that it is no nurse possesses the sufficient immunity (an utopian) scenario (that is, $\phi = 0$). On the contrary, the BBD, (3) is more realistic and versatile enough for any scenario where many, if not all, possess the sufficient immunity. The variance, $\mathrm{var}(Y|\pi,\phi)$ of the BBD (3) is

$$\mathrm{var}(Y|\pi,\phi) = E(Y|\pi,\phi)[1 - \frac{E(Y|\pi,\phi)}{n}]. \quad (7)$$

The variance is a measure of volatility. A larger variance means a greater volatility. A higher volatility in the incidences of infected nurses is indicative of an erratic and smaller proportion of nurses with sufficient immunity.

Another useful property of the BBD (3) is its survival function (SF). The hospital administrators might not want more than a minimal infection number, $(\tau - 1)$ of infected nurses. In specific, when $\tau = 1$, then it is a zero infection. One wonders about the probability of maintaining the zero infection policy. This article explores it later with the Toronto data in Table 1, using the survival function (SF) of BBD (3) which is derived now.

Note that the survival function, $\Pr(Y \ge \tau|n,\pi,\phi)$ of BBD (3) portrays the probability of experiencing τ or more infected among the n nurses who treated contagious patients. A higher survival function's value would demand a refinement of the infection policy or hospital administration. The SF for BBD (3) is

$$\Pr(Y \ge \tau|n,\pi,\phi) = \Pr[F_{2\tau,2(n-\tau+1)} \le \frac{(n-\tau+1)\pi}{\tau(1-\phi-\pi)}], \quad (8.a)$$

where $\Pr[F_{m,q} \le y]$ is the cumulative F- distribution function with m numerator and q denominator degrees of freedom (DF). The cumulative F-distribution is widely publicized. However, the odds of maintaining the zero infection policy is $\frac{\Pr(Y=0|\pi,\phi\ne 0)}{\Pr(Y>0|\pi,\phi\ne 0)} = [\{\frac{1-\phi}{1-\phi-\pi}\}^n - 1]^{-1}$ when all nurses in the group have the sufficient immunity. Likewise, in an utopian scenario when no nurse in the group has the sufficient immunity (that is, $\phi = 0$), the SF (8.a) reduces to

$$\Pr(Y \ge \tau | \pi, \phi = 0) = \Pr[F_{2\tau, 2(n-\tau+1)} \le \frac{(n-\tau+1)}{\tau} Odds(\pi)] \quad (8.b)$$

where the $Odds(\pi) = \frac{\pi}{(1-\pi)}$ is the odds for a nurse to get infected. By sketching the graphs of (8.a) and (8.b) together in terms of the probability to have at least $\tau = 1, 2, ..., n$ number of infected nurses reveal their differences due to $\phi \ne 0$ and $\phi = 0$.

The odds of maintaining the zero infection policy in the absence of nurses with sufficient immunity is

$$\frac{\Pr(Y = 0 | \pi, \phi = 0)}{\Pr(Y > 0 | \pi, \phi = 0)} = [\{1-\pi\}^{-n} - 1]^{-1}.$$

Their odds ratio of maintaining the zero infection policy with a mixed nurses in the group in so far as sufficient immunity is

$$(1 - \frac{\phi}{1-\pi})^n (\frac{1-[1-\pi]^n}{[1-\phi]^n - [1-\phi-\pi]^n}) \approx e^{-\phi Odds(\pi)} (\frac{e^{\pi}}{e^{\pi} - 1}). \quad (9)$$

With the two probability-informatics: the proportion (4) lacking virility and the proportion (5) in the reserve group of nurses, we proceed to estimate the model parameters using the maximum likelihood principle and a random sample $y_1, y_2, .., y_r$ of size $r \ge 2$ from a BBD (3). For this purpose, let $\bar{y} = \sum_{i=1}^{r} y_i / r$ and $s_y^2 = \sum_{i=1}^{r} (y_i - \bar{y})^2 / (r-1)$ be the sample mean and variance respectively. The maximum likelihood estimators (MLEs) over other estimators are preferable because of its invariance property[6]. That is, the MLE of a function of the parameters is simply the function of the MLE of the parameters. The log-likelihood function is

$$\ln L(\phi, \pi_{\phi}) = r\bar{y}[\ln \pi_{\phi} - \ln(1-\phi)] + r(n-\bar{y})[\ln(1-\phi-\pi_{\phi}) - \ln(1-\phi) + \sum_{i=1}^{r} \ln \binom{n}{y_i}]. \quad (10)$$

Simplifying and solving simultaneously the score functions $\partial_{\pi} \ln L = 0$ and $\partial_{\phi} \ln L = 0$, the MLE of the parameters in (11) and (12) are obtained. That is,

$$\hat{\phi}_{mle} = \frac{s_y^2 - \bar{y}(1-\frac{\bar{y}}{n})}{s_y^2 + \bar{y}(1-\frac{\bar{y}}{n})} \quad (11)$$

and

$$\hat{\pi}_{mle,\hat{\phi}} = \frac{\bar{y}\left|(1-\hat{\phi}_{mle})\right|}{n} \quad (12)$$

In a particular data, when the sample variance asymptotically converges, that is, $s_y^2 \to n\bar{y}(1-\frac{\bar{y}}{n})$, note that the MLE of the fear factor, $\hat{\phi}_{mle} \to 0$ in (10). It then means that the data point out under a negligible proportion of nurses with sufficient immunity. Does it happen? We will examine it later in the article with the Toronto hospital data. To examine whether the proportion with sufficient immunity is insignificant, likelihood ratio test[7] (LRT) needs to be done. Under the assumption $\phi = \phi^* \in [0,1)$, the likelihood ratio is

$$-\ln \Re_* = -\ln L(\phi_*, \hat{\pi}_{mle,\phi=\phi_*}) + \ln L(\hat{\phi}_{mle}, \hat{\pi}_{mle,\hat{\phi}_{mle}}) = \frac{2rs_y^2(1-\hat{\phi}_{mle})(\hat{\phi}_{mle} - \phi_*)}{(1+\hat{\phi}_{mle})}. \quad (13)$$

The expression (13) follows a non-central chi-squared distribution with non-centrality parameter $\delta_* = \left|\frac{(\hat{\phi}_{MLE} - \phi^*)}{\text{var}(\hat{\phi}_{MLE})}\right|$ where $\text{var}(\hat{\phi}_{MLE})$ is a diagonal element in the variance-covariance matrix $\Sigma = [\begin{matrix} \text{var}(\hat{\phi}_{MLE}) & \text{cov}(\hat{\phi}_{MLE}, \hat{\pi}_{MLE,\hat{\phi}_{MLE}}) \\ \text{cov}(\hat{\phi}_{MLE}, \hat{\pi}_{MLE,\hat{\phi}_{MLE}}) & \text{var}(\hat{\pi}_{MLE,\hat{\phi}_{MLE}}) \end{matrix}] = I^{-1}$ which is the inverse of the Fisher's information matrix $I = E[\begin{matrix} -\partial_{\phi\phi}^2 \ln L & -\partial_{\phi\pi}^2 \ln L \\ -\partial_{\pi\phi}^2 \ln L & -\partial_{\pi\pi}^2 \ln L \end{matrix}]$ evaluated at $(\hat{\phi}_{MLE}, \hat{\pi}_{MLE,\hat{\phi}_{MLE}})$. After algebraic simplifications, we note that the information matrix

$$I = \begin{bmatrix} \frac{nr\pi}{(1-\phi)^2(1-\phi-\pi)} & \frac{nr}{(1-\phi)(1-\phi-\pi)} \\ \frac{nr}{(1-\phi)(1-\phi-\pi)} & \frac{nr}{\pi(1-\phi-\pi)} \end{bmatrix}$$

is singular. The regular inverse matrix is not possible but a generalized inverse[8], $\Sigma = I^{-}$ is possible. The generalized inverse has the property that $\Sigma I \Sigma = \Sigma$. It is,

$$\Sigma = I^{-} = \begin{bmatrix} \frac{nr}{\pi(1-\phi-\pi)} & 0 \\ 0 & 0 \end{bmatrix}$$

Hence, the estimate of the non-centrality parameter is

$$\hat{\delta}_* = \left| \frac{\hat{\pi}(\hat{\phi}_{mle} - \phi_*)(1-\hat{\phi}_{mle}-\hat{\pi})}{nr} \right| \quad (14)$$

It is well known[6] that a non-central chi-squared distribution with a non-centrality parameter δ is approximately $(1+\frac{\delta}{1+\delta})$ times the central chi-squared distribution with $(\frac{[1+\delta]^2}{1+2\delta})$ degrees of freedom (DF). Hence, the null hypothesis $H_0: \phi = 0$ can be rejected in favor of the research hypothesis $H_1: \phi > 0$, when $\frac{2rs_y^2(1-\hat{\phi}_{mle})\hat{\phi}_{mle}}{(1+\hat{\phi}_{mle})}$ exceeds its critical value $(1+\frac{\hat{\delta}_0}{1+\hat{\delta}_0})\chi^2_{(\frac{[1+\hat{\delta}_0]^2}{1+2\hat{\delta}_0})DF,\alpha}$ at a chosen significance level, α.

In other words, the p-value to reject the null in favor of the research hypothesis is

$$p-\text{value} \approx \Pr[\chi^2_{(\frac{[1+\hat{\delta}_0]^2}{1+2\hat{\delta}_0})DF} > \frac{2nrs_y^2(1-\hat{\phi}_{mle})\hat{\phi}_{mle}}{(1+\hat{\phi}_{mle})(1+\frac{\hat{\delta}_0}{1+\hat{\delta}_0})}]. \quad (15)$$

The (statistical) power is the probability of accepting a true specific research hypothesis $\phi^* = \phi_1 \neq 0$. That is, for a specified significance level, α

$$\text{statistical\_power} \approx \Pr[\chi^2_{(\frac{[1+\hat{\delta}_*]^2}{1+2\hat{\delta}_*})DF} < \frac{(1+\frac{\hat{\delta}_0}{1+\hat{\delta}_0})\left|(1-\frac{\phi_1}{\hat{\phi}_{mle}})\right|\chi^2_{(\frac{[1+\hat{\delta}_0]^2}{1+2\hat{\delta}_0})DF,\alpha}}{(1+\frac{\hat{\delta}_*}{1+\hat{\delta}_*})}]. \quad (16)$$

RESULTS

In In this section, the derived results of section 2 are illustrated using the # infected among n = 32 nurses who provided care to SARS patients in the Toronto hospital as in Table 1. The sample size is $r = 16$. Note that $Y_i, i = 1,2,..r$, $0 \le \phi < 1$, $0 < \pi < 1$, and n denote respectively the number of infected nurses in each of the $r = 16$ patient care services, the proportion of nurses with sufficient immunity, and the proportion of infected nurses, and the group size in the services. Their MLEs are $\hat{\phi}_{mle} = 0.25$ and $\hat{\pi}_{mle,\hat{\phi}} = 0.10$ using (11) and (12) respectively. Assuming that none of the nurses had sufficient immunity, the infection rate of nurses would have been estimated to be $\hat{\pi}_{mle,\phi=0} = 0.13$.

The null hypothesis $H_0: \phi = 0$ refers a negligible proportion of the nurses with sufficient immunity. Suppose that a half of the nurses with sufficient immunity is the specific research hypothesis (that is, $H_1: \phi_1 = 0.5$). The probability of rejecting the true null hypothesis is p-value and it is 0.001 according to (15). The probability of accepting a true specific research hypothesis is the (statistical) power as noted in (16) and it is 0.948 with $H_1: \phi_1 = 0.5$, according to (16). The odds for maintaining zero infection policy are 0.009 with $\phi = 0$ and 0.034 with $\phi \neq 0$. The informatics on the lack of virility is $\Pr(\bar{\Re}|\bar{H})$ = 0.865, according to (4). The informatics on the reserve group proportion, $\Pr(H|\bar{\Re})$ = 0.280, according to (5).

The probability, $(\frac{\hat{\phi}}{1-\hat{\phi}})\hat{\pi}$ for no nurse to be infected is 0.033. The Odds ratio for maintaining zero infection policy, between the groups (one with $\phi \neq 0$ and another with $\phi = 0$) is $e^{-\phi Odds(\pi)}(\frac{e^{\pi}}{e^{\pi}-1})$ = 10.13, according to (9). In other words, for every one situation with $\phi = 0$, there are 10 situations with $\phi \neq 0$ to maintain zero infection policy. Recall that ϕ is the probability for a nurse to have sufficient immunity when providing care to contagious patients like SARS in an emergency department of a hospital. A sketch of the graphs of (8.a) and (8.b) together in terms of the probability to have at least

$\tau = 1, 2, ..., 32$ number of infected nurses reveals their differences due to $\hat{\phi} = 0.252$ and $\phi = 0$ in the Figure 3.

Notice that the probability for at least a specified number of infected nurses is consistently more when $\phi = 0$ than when $\hat{\phi} = 0.252$. Without the BBD (3), we would have missed these informatics in the Toronto data in Table 1.

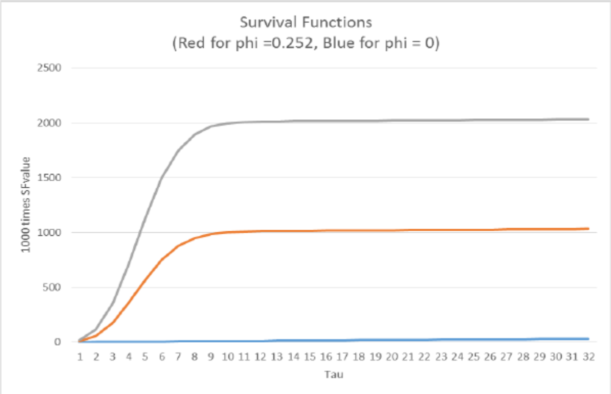

Figure 3: Comparison of survival functions with $\hat{\phi}$= 0.252 and ϕ = 0.

DISCUSSION

This article has derived and illustrated a bumped-up binomial distribution for the total outcomes of *n* independent identically distributed Bernoulli processes for a scenario in which the probability of one among the two dichotomous outcomes is under-estimated due to several reasons of practicality. More research work would help to explore and assess the significance of predictors which impact the presence or absence of sufficient immunity among the healthcare professionals working within a hospital site infectious scenario. This kind of scenarios occur not only in medicine and health arena but also in marketing, finance, economics, sports, trade, management, engineering, earthquake, e-business, communication, and other studies.

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