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Study on Image Quality in Teledermatology and Telepathology of Telemedicine Using a Digital Camera

Krishna Bahadur Rai
Department of Physics, Patan Multiple Campus, Tribhuwan University, Kathmandu, Nepal
Email: krishnarai135@gmail.com

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Abstract:
Telemedicine is the delivery of health care and exchange of health care information across distance by the use of electronic communication and information technology. Telemedicine (Teledermatology and Telepathology) are being increasing popular and advanced. In ROC curve analysis, it is found that the area under the ROC curve for dermatology is 0.922 saying that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 92% of the time. For histology and cytology, areas under ROC curve are 0.909 and 1.000 respectively. These larger areas indicate high diagnostic accuracy through the high image quality. Again, the P-value for dermatology, histology and cytology are respectively 0.000, 0.000 and 0.001 and all the P-values are low i.e., $P < 0.05$ which is statistically significant. Therefore, this confirms that an image has good help to detect disease for the doctor's diagnosis. For detection of disease through images, these images must have good and high quality.

Keywords: Dermatology, Diagnosis, Image, Pathology, ROC, Telemedicine

Introduction
Telemedicine is the delivery of health care and exchange of health care information across distance by the use of electronic communication and information technology. It includes the diagnosis, prevention and treatment of diseases, continuous health care and medical

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education of providers and consumers, research and evaluation considering the distance is an issue (Cipolat & Geiges, 2003). Hence, more simply, telemedicine is medicine at a distance. Telemedicine or telecommunication in medical services also plays important role in the case of emergencies in the remote environment (Craig & Patterson 2005) such as the Dolpa, Olangchunggola, Kimathanka, etc. of our country Nepal with weak and unstable economy where health care services are often not a priority. The quality of telemedicine evidence lacks not only in terms of data collected and analyzed but also in terms of the method of image taken and its use (Ekeland, Bowes, & Flottorp, 2010). The consideration for the image quality using digital camera with important features such as the setting, macro-capabilities, method of image transfer and power recharging is an essential component of store-and-forward telemedicine (Patricoski & Ferguson, 2009). Teledermatology deals with the transmission of macroscopic skin images for expert consultation. It has been used for consultation between primary care centers or general practitioners and experienced dermatologists. Teledermatology not only provides an adequate service to rural areas but, in addition offers new income sources for the experts. Video conferencing systems and high-resolution television cameras permit the transmission of still and live images during the patient's examination for expert consultation (Whitten, 2003). Telepathology (Telehistology and Telecytology) is the performance of pathology at a distance using the available telecommunications links. It enables pathologists to render diagnosis and to consult remotely. Basically, the viewing of tissue and cellular specimens by the naked eye or via a microscope is replaced by transfer of the corresponding images to a video monitor. The images are acquired by video cameras or by digital cameras mounted at the place for gross examinations or on a microscope, and transmitted to the examining pathologist. Telecommunication links the place of image acquirement to the workstation for diagnostic examination. Both the sender and receiver need computerized equipment for accurate results (Kumar, 2009). These technical solutions are an excellent solution in the search for improved medical diagnosis by transmission of adequate, non-biased information which can provide the most appropriate diagnostic interpretation and classification (Whitten, 2003; Whited, Edison, & Pak, 2008). So telemedicine is a fusion of three dynamic and complex industries: medicine and health care, information and telecommunication given in fig.1 (Giilar & Ubeyli, 2002).

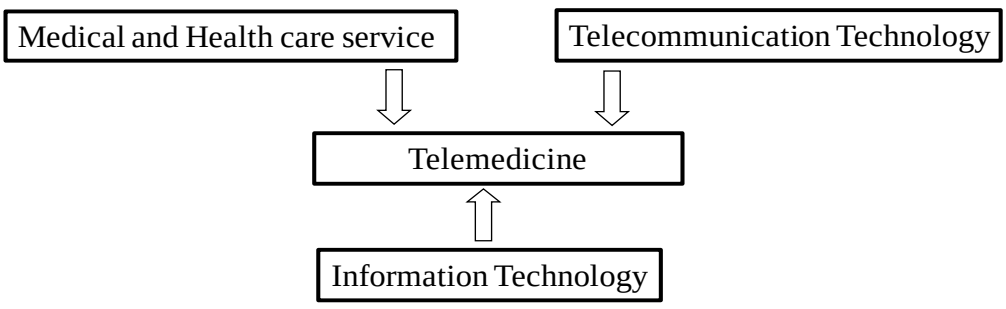

Figure 1: Telemedicine and related areas (Giilar & Ubeyli, 2002)

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The image visibility is affected by many parameters such as patient exposure, light on object, instrumented condition, band-width of telecommunications, methods of acquisition of image and display system. Furthermore, the light which is the main disturbance of image quality depends on the shutter speed, aperture, focal length, and sensitivity of camera. The other disturbances of image quality are lack of information technology, unavailability and high cost of telecommunications services in rural and some urban communities.

Receiver Operating Characteristics (ROC) Analysis: Basic Principles and Applications in Telemedicine

Receiver Operating Characteristic (ROC) analysis has increasingly been used for telemedicine dependent on image and the ability of an image to diagnose a disease. ROC analysis starts with the proposition that an observer exists and the observer uses some decision criterion or confidence threshold to reach a decision (Belle, Fisher, Heagerty, & Lumley, 2004). The ROC curve is a graph of True positive factor (TPF) or sensitivity versus False positive factor (FPF) and hence among the relative frequencies of true positive, false positive, true negative, and false negative decisions - as a decision threshold is varied. By appropriate choice of the decision threshold, a decision maker or observer can operate at (or near) any desired compromise that lies on the curve. The TPF and FPF, both of which are independent of disease prevalence and it does not depend on the prevalence of disease in the actual population to which the test may be applied. Thus, ROC analysis provides a description of disease detectability that is independent from both disease prevalence and decision threshold effects (Yadav, Singh & Gupta, 2019).

Sensitivity, specificity and predictive value are needed for ROC analysis and these are aspects of data accuracy and are used in health care. The sensitivity or True Positive Fraction (TPF) describes the fraction of diseased patients that actually has a positive test result. A measure is sensitive to the extent that it identifies every case in which the property of interest is truly present (cell a, Table 1). If the measure is not sensitive, it will not detect the property of interest when it is present (cell c, Table 1) i.e. False Negative. Specificity is the aspect of measurement that results in exclusion of cases when property of interest is truly absent (cell d, Table 1). The specificity or True Negative Fraction (TNF) describes the probability of negative test result in non diseased individuals. If the measurement is not specific, it will falsely detect the property of interest when it is not present (cell b, Table 1) i.e. False Positive. The accuracy of a test or measure is dependent upon the number of false positives and false negatives that occur as a result of using the measure. If the test is accurate, the number of false positives and false negatives will be low. The predictive value is the proportion of positive tests that are truly positive (a/a+b). The predictive value of a positive test increases as sensitivity and specificity increase (Osborn, 2006); Chernick & Friis, 2003).

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In this table 1, the rows represent the true situation, the presence or absence of the performance indicator. The columns represent the possible results of the measure for the performance indicator of interest. The test is positive when it tells us that the performance is present and negative when it tells us that the performance indicator of interest is not present.

Table 1: Assessing Sensitivity and Specificity of a Measure

Test/Measure	Performance Indicator Present	Performance Indicator Absent	Total
Positive	a (True Positive)	b (False Positive)	a+b
Negative	c (False Negative)	d (True Negative)	c+d
Total	a+c	b+d	a+b+c+d

Sensitivity	a/(a+c)
Specificity	d/(b+d)
Predictive value	a/(a+b): the predictive value of a positive
	c/(c+d): the predictive value of a negative

To determine the specificity and sensitivity of a proposed measure, test of the measure may be conducted and the results can be displayed (Yadav, Singh, & Gupta, 2019).

Objective of the Study

The origin of telemedicine was due to the limited radius of medical treatment when the physician was available. In the telemedicine study, teledermatology and telepathology (telehistology and telecytology) are being ever increasing popular and advanced. The use of images of teledermatology and telepathology for clinical diagnosis are not always without risk because sufficient quality of images may not be there. To get sufficient diagnostic information, sufficient quality of images must be used such that detection display and interpretation should be optimal. An image taken depends upon various factors and specially has an effect on diagnostic of disease. An optimized image procedure is one in which image quality of patient characteristics is properly balanced. The image visibility is the key component that determines patient problem. However, obtaining good image quality of teledermatology and telepathology is the main problem which actually refers to the visibility of the image to diagnosis the disease. In this context, we did research on study of good image quality formation and transmission in diagnostic teledermatology, telehistology and telecytology.

Methodology

Among the various types of telemedicine, the suitable technology for our country is store and forward telemedicine (Pradhan, 2005). This paper explains the telemedicine based on store

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and forward technology (prerecorded telemedicine) in which the acquisition of diagnostic information are collected at the remote site then this storage of information are delivered to the expert site through dial-up internet connection as an e-mail attachment to the central computer such that the referring expert doctor enters and access the data of clinical information and digital images independently at his or her convenient time in a computer. After analysis of the information, the prerecorded telemedicine process may be reversed by transmitting the results of any episode back to the remote site (Mea, 2005). Figure 2 and figure 3 show the medical specialties covered in the areas of dermatology and pathology.

For this work, the three different places of Nepal i.e. AMDA, Damak; AMDA, Butwal and Siddhi Memorial Hospital, Bhaktapur were chosen. Images were obtained using Nikon Coolpix 4500 Camera with four megapixel. Then, these images are stored in JPEG format at varying levels of compression which are sufficient for medical still image. For image compression, HealthNet Nepal has used image compression software called LZ77 to reduce the amount of memory required to store an image. The Camera has compact lightweight swivel design such that it can be used with binocular microscope. Once images are stored in the computer, a graphic package incorporated in the client software of HealthNet is used to crop for minimize file size and to annotate the images for better description of the clinical problem. This graphic package also allows rotation, brightness, contrast, color balance and conversion to black and white.

Results and Discussions

Information regarding measures of image quality have been assumed to deal with the clarity and accuracy for the diagnosis of diseases.

Data Collection

The total cases observed in different areas for telemedicine are 129, which is classified as below: (1) Dermatology: 75 cases (2) Pathology 54 cases (Histology: 34 cases and Cytology: 20 cases).

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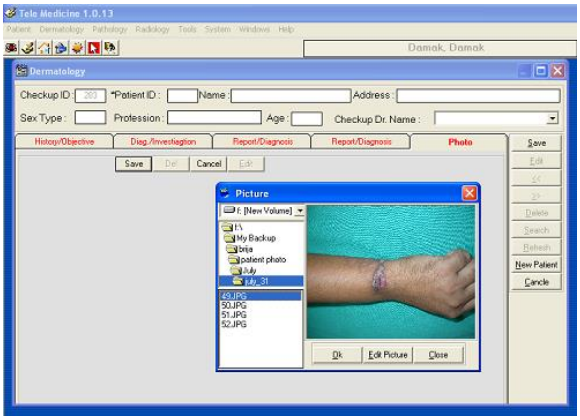

Figure 2: Image of dermatology

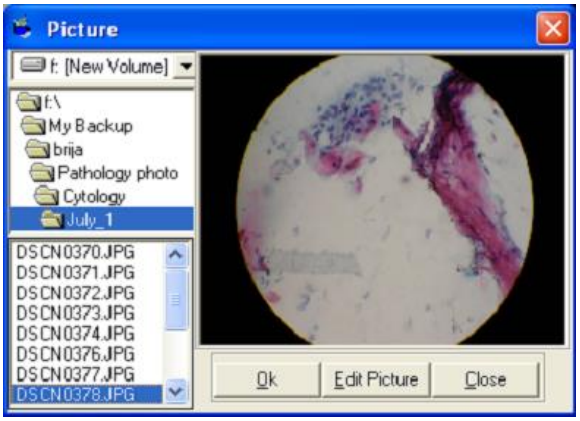

Figure 3: Image of pathology

The lists of cases diagnosed through clinical history along with images are given in the table 2, table 3 and table 4. The data were collected to generate Receiver Operating Characteristics (ROC) curves.

Table 2: Case List for Dermatology

S. N.	Case title	No. of patients	S. N.	Case title	No. of patients
1.	Popular growth	1	29.	Alopacia areata	1
2.	Itching	10	30.	Pyoderma gangrenosum	1
3.	Chicken pox	3	31.	Xeroderma pigmentosas	1
4.	Non Itching	1	32.	Allergic contact dermatitis	3
5.	Purpura HSP	1	33.	Varicella	1
6.	Hair loss	1	34.	Pityriasis Versicolor	1
7.	Injury	1	35.	Hypotrophic lichen planus	1
8.	Itching lesion	1	36.	Scabies	1
9.	Chillblain of fingers	1	37.	Lupus Vulgaris	1
10.	Depigmentation	1	38.	Tropic ulcer	1
11.	Insect allergy	1	39.	Sporotrichormn	1
12.	Baby with nodular lesions	1	40.	Ventura flora	1
13.	Lichen planus	1	41.	Common wart	1
14.	Coloring effects	1	42.	Lichen simplex chronicus	1
15.	Impetigo contagiosa	1	43.	Pityriayses	1
16.	Cement allergy	1	44.	Facial wart	1
17.	Insect irritation	1	45.	Chronic Paromychia	1
18.	Lips problem	1	46.	BL – LL	1
19.	Sorasis	1	47.	Leprosy	1

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20.	P sorasis	1	48.	Leprosy (chronic)	2
21.	Herpus Zoster	4	49.	Leprosy (vecicolor)	1
22.	Infected Head	1	50.	Leprosy (Erythenianodoison)	1
23.	Theula	1	51.	Contact eczemz	1
24.	Chronic eczema	1	52.	Foot	1
25.	Janai khatira	3	53.	Vitiligo	1
26.	Ulcertive growth	1	54.	Planter	1
27.	Tuberous selerosis	1	55.	Atrophic dermatitis	1
28.	Rapidly growing mass of check	1	56.	Facial pimples	1

Table 3: Case List for Histology

S. N.	Case title	No. of patients	S. N.	Case title	No. of patients
1.	Larynx	1	17.	Cervical growth	1
2.	Neck swells	2	18.	Eye lid	1
3.	Polypectomy	1	19.	Cyst	1
4.	Appendix	1	20.	Cervical Polyp	1
5.	Abdomen pain	1	21.	Swelling	1
6.	Duodenal pain	1	22.	Vaginal biosopy	1
7.	Fistula	1	23.	Tumor	1
8.	TAH and BSO	1	24.	Check cheek	1
9.	Endoscopic	1	25.	Vaginal hysterectomy	1
10.	Oesophagal growth	1	26.	Bleeding	1
11.	Cervical	1	27.	Follicular adenoma	1
12.	Thysoid module	1	28.	Appendix	2
13.	Left vocal cord	1	29.	Rectal polyp	1
14.	Nasal cavity	1	30.	Missed absortion	1
15.	Prostatectomy	2	31.	Cholecystectomy	1
16.	Cervix	1			

Table 4: Case List for Cytology

S. N.	Case title	No. of patients	S. N.	Case title	No. of patients
1.	Lipoma	1	7.	PAP Smear	2
2.	Neck swell	1	8.	Haematoma over rt upper arm	1

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3.	PID	1	9.	Atrophied uterus	1
4.	FNAC	9	10.	Smear	1
5.	Fileroadenoma	1	11.	Intra auricular cyst	1
6.	Celvities	1			

Steps in performing the Statistical analysis

For plotting ROC curve, two steps rating method is used. Firstly, a dichotomous variable representing 0 = negative and 1 = positive has been used to indicate the quality of image. Secondly, the dichotomous variable based upon positive quality of image is further rated based on five point scale such as (1) definitely or almost definitely negative; (2) probably negative; (3) possibly positive; (4) probably positive; and (5) definitely or almost definitely positive. The use of five categories seems to represent a reasonable compromise between the needs of ROC analysis and the precision with which an observer can be expected to reproduce his ratings. This five point rating scale is used to calculate 'Predicted Probability'. This predicted probability along with dichotomous variable can be used to plot ROC curve in order to provide a visual impression of the reliability of the points. Statistical Package SPSS 11.5 was used for calculating 'Predicted Probability' using logistic regression model. Based on dichotomous variable and 'Predicted Probability' ROC curve in graphic form was plotted.

A representation and interpretation of the area under a ROC curve obtained by the rating method based on the image of patient characteristics is presented in figure 4, figure 5 and figure 6 for dermatology, histology and cytology respectively.

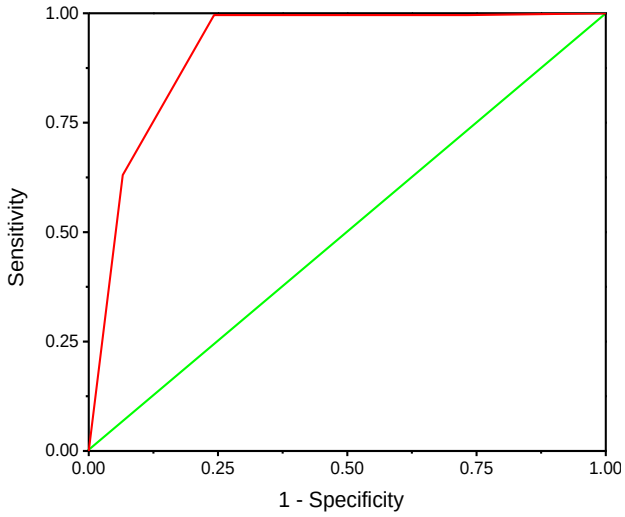

Figure 4: ROC Curve for Dermatology

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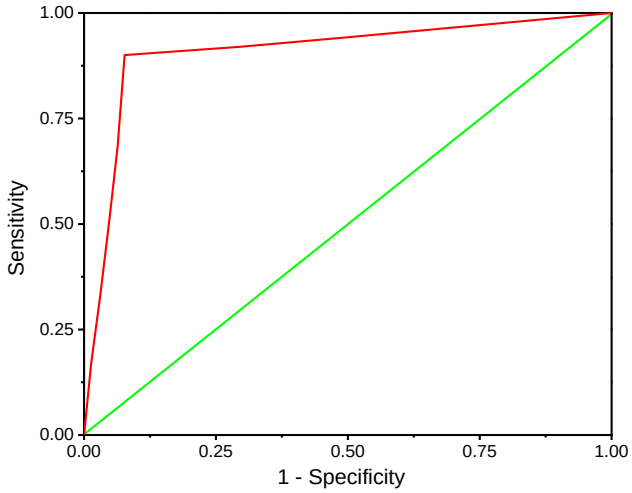

Figure 5: ROC Curve for Histology

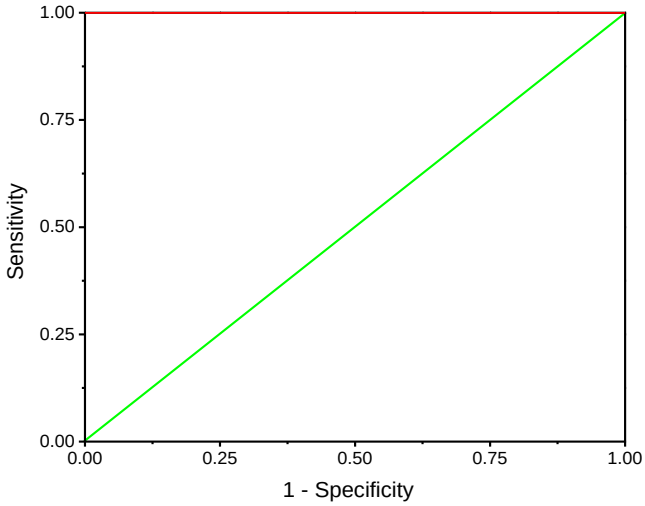

Figure 6: ROC Curve for Cytology

One of the most popular measures of the accuracy of a diagnostic test is the area under the ROC curve. The ROC curve area can take on values between 0.0 and 1.0. A test with an area under the ROC curve of 1.0 is perfectly accurate because the sensitivity is 1.0 when the FPF is 0.0. In contrast, a test with an area of 0.0 is perfectly inaccurate. That is, all patients with disease are incorrectly given negative test results and all patients without disease are incorrectly given positive test results. With such a test it would be better to convert it into a test with perfect accuracy by reversing the interpretation of the test results. The practical lower bound for the ROC curve area is then 0.5. The line segment from 0,0 to 1,1 has an area of 0.5; it is called the chance diagonal. At (0,0) the observer is never convinced and at (1,1), the observer is always convinced (Aryal & Spyrou, 1991). If we relied purely on guessing to distinguish patients from patients without disease, then the ROC curve would be expected to

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fall along this diagonal line. Diagnostic test with ROC curve area greater than 0.5 have at least some ability to discriminate between patients with and those without disease. The closer the ROC curve area is to 1.0, the better the diagnostic test.

The value for the area under the ROC curve in figure 4 given by the table 5 is 0.922 in asymptotic 95% confidence interval having lower bound 0.892 and upper bound 0.952 for dermatology means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 92% of the time. In figure 5, an area given by table 5 is 0.909 in asymptotic 95% confidence interval having lower bound 0.884 and upper bound 0.934 for histology means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 90% of the time. In figure 6, an area for cytology given by the table 5 means that a randomly selected individual from the positive group has a test value larger than that for a randomly chosen individual from the negative group by 100% of the time. Sometimes, the variable under study cannot distinguish between the two groups, i.e. where there is no difference between the two distributions, the area will be equal to 0.5 (the ROC curve will coincide with the diagonal).

Table 5: Area under the Curve

Test Result Variable(s): Predicted Probability					
Area	Std Error	P-value	Asymptotic 95% Confidence Interval		
			Lower Bound	Upper bound	
0.922	0.015	0.000	0.892	0.952	Dermatology
0.909	0.013	0.000	0.884	0.934	Histology
1.000	0.000	0.001	1.000	1.000	Cytology

The P-value is the probability that the sample area under the ROC curve is found. The true area under the ROC curve is 0.5 (null hypothesis: Area = 0.5). If P is low (P<0.05) then it can be concluded that the area under the ROC is significantly different from 0.5 (Maheiu, Written & Allen, 2000) and therefore there is evidence that image has an ability to detect disease. The P-values from the Table 5 are 0.000, 0.000 and 0.001 for dermatology, histology and cytology respectively in which all the P are low (P<0.05). So, it can be concluded that images have an ability to detect disease. For detection of disease through images, these images must have good and high quality.

Test and compare the baseline medical knowledge of primary care physicians and clinical experts

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We also compared the baseline medical knowledge of primary care physicians with clinical experts. For testing the capacity of expert doctor in the diagnosis of cases through image, the SPSS calculation for Chi-square (χ^2) goodness-of-fit test was done (Chernick & Friis, 2003). Here, we are comparing observed frequency (i.e., actual frequency) with expected or theoretical frequency in a distribution. However, the expected counts are based on the collected data and observed counts are based on knowledge of the expert doctor given in table 6. This table 6 displays the observed and expected frequency. If the calculated χ^2 is small, there is closed agreement between the observed and expected frequencies. As the discrepancy between the observed and expected frequencies increase, the calculated χ^2 increases and the more likely we are to reject the null hypothesis and conclude that the test capacity of expert doctor in the diagnosis of cases through image fails due to low quality of image.

Here comparing observed frequencies with the expected frequencies across two categories rows on the variable Expert Doctor. The degree of freedom (df) is based on the number of categories (k) and is equal to the number of categories minus 1 (i.e. k – 1). Therefore, the degree of freedom 2 – 1 = 1 and for 1 df, the critical value of chi-square at 5% level = 3.841. Since the calculated value is less than critical value so it can be said that statistically there is no difference in the diagnosis among primary care physicians and the expert doctors. SPSS reports that chi-square as 23.059. P=0.000 which is statistically significant (P<0.05). The assumptions for the chi-square goodness-of-fit test are given in table 6.

Table 6: SPSS output for Chi-square Goodness-of-fit

Expert Doctor				
	Observed No.	Expected No.	Residual	Category
	3	17.0	-14.0	no
	31	17.0	14.0	yes
Total	34	34		

Test Statistics	
Expert Doctor	
Chi-square	23.059
Df	1
P-value	0.000

In developing our system, consideration was given in establishing guiding principles for telemedicine services in dermatology and pathology. However, the gold standard for any

specialist referred remains the traditional way of consultation i.e. in case of Pathology viewing through microscope and in case of dermatology face to face consultation.

Conclusion

We have used the simple principle by adopting affordable system appropriate to our needs. The store and forward system offers a more practical and less expensive solution. Store and forward methods allow the use of low-cost equipment, low bandwidth connectivity, and asynchronous consultation.

In this work, digital cameras have emerged as an efficient method for obtaining digital images. Due to which I have evaluated the effectiveness of digital photography images for dermatology, histology and cytology diagnosis. And found digital camera generated images to be of sufficient quality so that high diagnostic concordance in the histology and cytology diagnosis. The images of dermatology and pathology sent from remote rural areas are sufficient for the diagnosis of cases. The findings show that there was no difference between the results obtained by diagnosis using images compared to using conventional methods of diagnosis.

Finally this research says that the good image quality is necessary for correct diagnosis in teledermatology and telepathology (histology and cytology). For the high quality medical care to be provided, the expertise medical care provider is an important factor.

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