STUDY OF NAIL UNIT USING IMAGE PROCESSING METHODS

Dr. M. Renuka Devi
Associate Professor in MCA
SNS College of Technology,
Coimbatore, Tamil Nadu. India

Thahira Banu.V
Part-Time Research Scholar,
Bharathiar University,
Coimbatore, Tamil Naudu. India

Abstract— **Digital image processing plays a key role in medical imaging. Nail diagnosis is one of the methods in medical imaging to predict the diseases. Nails can reflect the present health condition, genetically inheritance information, and historical information of drug or alcohol usage for the past months or even a year, etc. This paper explores the existing research works related to nail plate and nail matrix as tool for bio-metric system, nail fold capillaries to identify the disease severity levels & affected organs, nail surface as evidence in forensic science to identify the chemical effects, nail samples to identify drug intake and abuse etc. So that, Nail is analyzed by various imaging types and processing algorithms to recognize the person's uniqueness, health condition and its history. This paper also identifies the research challenges and issues.**

Keywords—Finger nail analysis; abnormalities of nails; nail-fold capillaroscopy NFC; nail disease prediction; nails in forensic sciences;nails in bio-metric recognition systems.

I. INTRODUCTION

Greek words Onuks- nails and Logia-study of, which 'Onychology' means the study about fingernails and toenails. Nails are made of a tough protective protein called keratin. *Nail matrix* is the tissue beneath the nail plate contains nerves, lymph and blood vessels. It produces *nail plate* cells. The growth depends upon the nutrition it receives. As new nail plate cells are made, they push older nail plate cells forward; to be compressed, flat, and translucent. It makes the capillaries in the nail bed below visible; resulting in a pink color. The whitish crescent-shaped *lunula* can best be seen in the thumb and may not be visible in the little finger. The *nail bed* is the skin beneath the nail plate. In old age, the nail plate becomes thinner so that these grooves become more visible. The *sinus* is the nail root i.e. the base of the nail underneath the skin. Nails grow at an average rate of 3 mm in a month. Fingernails require 3-6 months and toenails require 12-18 months to grow completely [1]. Actual growth rate depends upon age, sex, season, exercise level, diet, and hereditary factors. Nail growth is affected by disease, nutrition, medications, trauma, chronic illness, fever, and the aging process, chemical effects, pollution absorption, etc. Nails reveal the general state of health. The abnormalities are the clues for common medical problems or severe systemic diseases. Nail diagnosis is a method to predict the diseases, infections by analyzing capillaries appearance, microcirculations and hemorrhages under the nail plate [7]. Nail can be an additional tool for personal identification in biometric recognition systems. Nail matrix, nail bed and shape are unique to each person like fingerprint and iris [2][3]. Nail plate texture also considered but they are timely changeable

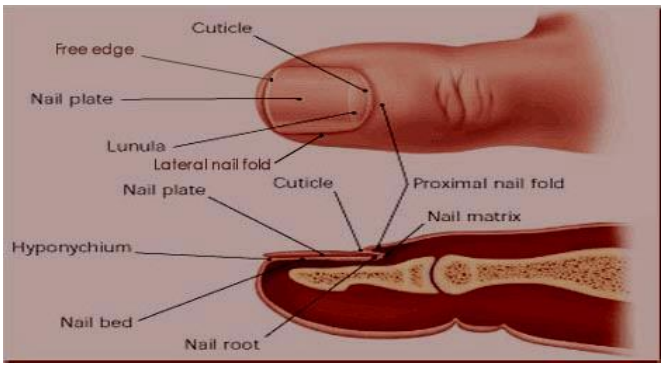

Fig: Anatomical structure of Thumb nail

Nails are best for research of external contamination; fingernail reflects the exposure for the last 6 months. The great toenail is less exposed to external contamination, which gives the information about the last 1-year. Hence, the nails growth is very slow; it is useful tool for retrospective analysis [1]. It is possible to identify and measure the liquoring and biological substances through nails. It provides a history of drug intake, toxin level and chemical effects that represents a unique substrate for forensic purposes. This paper is the survey about the nail unit used with image processing techniques. Chapter I is the background and anatomical structure of the nail. Chapter II narrates how the nail unit is captured and processed for various applications. Chapter III shows the merits and demerits of the existing research works.

II. IMAGING

The study of nail unit is divided into three application levels as follows:

A. Nails in medicine:

Since the nails are the last to receive oxygen because they are the farthest from the heart, they are often the first to show signs of disease processes. *CCD camera/digital camera* is used to store spatial information about the normal image, to capture the appearance of the nails. Usually nails are reflecting, so that lighting adjusting equipment or contrast

adjustment should be done manually/systematically. Sometimes *scanners* or special sensors also used to record the appearance of the fingernails. It is useful to measure nail shape, size, color and texture can be observed for further investigation like nail psoriasis or nail fungus or nail cancer. *Dermascope* images are also used for disease identifications.

UltraSonography is useful to detect glomus tumours of the fingertips and radio transparent foreign bodies, such as splinters. It is mainly used to measure tumor thickness >1mm from those of 1 mm or less. Characteristic ultrasound pictures are used to diagnose for psoriasis, glomus tumors, and myxoid cysts. The imaging clarity is based on the tissue structure, echogenicity, and several technical parameters [8].

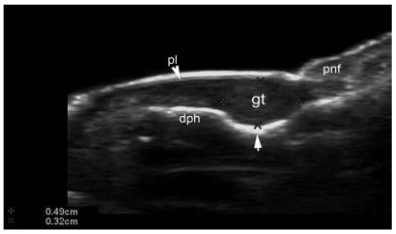

Fig-3**:** Glomustumor Remodeling of the bony margin of the distal phalanx (arrow) and the upward displacement of the nail plates, Normal sonographic (index finger, longitudinal view). Abbreviations; dph,-distal phalanx;; nb, nail bed; pnf- proximal nail fold; and pl-nail plate.

MRI imaging technique is useful to evaluate anatomical structure, bone appearance, calcification, tumor, cancerous cells, and fungi and to remove the nail plates for preserving the fingers etc. Radiography shows the high, intermediate and low signals for bones, nail matrix, connective tissue and fibrous cartilage, respectively. Lot of spatial and frequency domain algorithms are used for noise removal which has been the research issues for all types of machines and image.

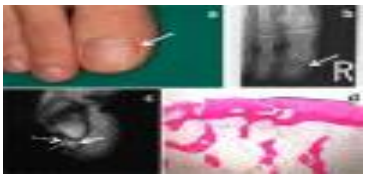

Fig: MRI image of Great toenail

In *Optical coherence tomography* (OCT) imaging, infrared light waves use to sends, and its reflection is measured and the intensity is imaged. The image data are displayed by assigning color or gray scales to each reflection according to the measured signal strength. It clearly reflects the anatomical structure of the nail unit. This technique is useful to diagnose nail fungus and nail psoriasis with additional use of dermoscope.

Microscopic imaging is mostly used for preclinical study for Rayhnaud Phenomenon RP (hand numbness), Systemic Sclerosis SSc (Skin based diseases), Dry Eye Disease DED (tears are dry and irritatory), and Connective Tissue Diseases CTD. It also rarely used to identify the diseases like diabetes, hypertension, acromegaly and psoriasis. This technique is also called Nailfold Capillaroscopy NC; use to analyze capillaries (blood vessels), hemorrhages, microcirculation under the nail plate and nail-folds [6]. Usually ring finger is tested because of best visualization. Some other imaging methods are also used to diagnose the nail unit in microscopic level like vivo capillaroscopy, (wide field panoramic) photomicrography, video capillaroscopy, vitro Raman spectroscopy, etc.

Fig: USB attached Microscpoe and Capillaries images

B. Nails in forensic sciences

The nail plate has longitudinal ridges like texture. These ridges are distinctive and used to identify the uniqueness even the twins in forensic field. These nail ridges may be best examined using *polarized light*. It is also taken by high quality camera.

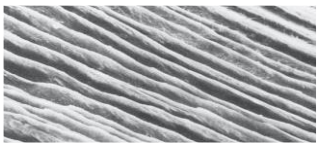

Fig: Scanning electron micrograph of the nail bed demonstrating longitudinal ridges.

Confocal microscopy provides 3D information about nail plate. It is useful to measure the nail plate thickness *in vivo*.

Doppler Imaging is used to identify the blood flow and also used with power angiography to detect blood vessels and flow. Doppler OCT imaging is useful to identify vascular tumors. Still it has the research challenges for more refined techniques for more specific and accurate diagnosis of drug intake and abuse, exposure to pollutants and may also help in the monitoring of some diseases from a simple nail clipping and usually great toenail is preferred.

Other techniques are, Scanning *electron microscopy* is used to analyze the nail plate structure. Transmission electron microscopy can be used to identify the relationship between the coenocytes of the nail plate. Vivo/vitro spectrometry, Raman spectroscopy are used to visualize the molecular, atom level movements, which is helpful to identify the blood particles of surroundings of the nail unit to analyze chemical exposure like Gadolinium, arsenic, cocaine intake or liquoring remaining [1].

C. Nails in Bio-metric systems

Researchers propose nail unit is one of the biometric for authentication. The nail matrix and nail plate texture pattern is distinctive and the images are observed by special equipment or by ordinary camera. Generally, thumbnail or index finger nail image is captured by CCD camera with illumination of a LED light or high-speed VGA camera. The camera can focus flooring and fluorescent lamp can be installed on the ceiling. Scanner or digital video camera with sensors are also used to observe fingerprint bio-metric and backside of palm to observe knuckle, finger shape, length, nail shape, texture, lunula size, etc. Palmistry also considered for the biometric. These features are considered as traits to identify the person.

III. COMPARATIVE STUDY- RESULTS & DISCUSSION

A. COMPARISION OF NC TECHNIQUES

The normal nailfold capillaroscopic pattern shows a regular disposition of the capillary loops along with the nailbed. The abnormalities of capillaries (giant capillaries, bushy capillaries, capillaries loop thickness, its length, density, number of capillaries) can signals the systemic/severe diseases. The capillaries size and count may vary due to age factor[14].

A digital video camera attached to a stereomicroscope is used to capture capillaries images to measure: linear capillary density, capillary width, capillary tortuosity, avascular areas, capillary disarrangement, and the number of abnormal vessels. Abnormalities were evenly distributed, so a 3 mm section of the middle portion of the nail fold was magnified 66 times (3mmof nail fold was equivalent to 19.8 cm on the computer screen). Then capillary density& width are manually measured from the screen, compared with the mean, median values to identify CTD ($p<0.001$) (P Dolezalova, 2003)[12].

Mark C. Hou et al.proposed computerized NFC (CNC) to measure the capillary density, width and blood flow velocity. USB based video camera with microscope captures the video at rate of 30 images/s. Median filter and K-means of filters are used to adjust the reflections in each image, then two similar images are cross-correlated and panoramic mosaic is used to provide the single image for major variations. Gaussian filter is used to reduce the noise. Capillaries width, density, blood flow velocity is calculated. Image enhancement is an important issue for noise removal. Laplacian or Gaussian and Skeleton algorithms are proposed to improve the quality of the images. Though commercial products for images analysis are available (example: Cap-Image, CapiScope, etc), it is time-consuming and not ready for clinical use. The proposed method is timesaving, still pattern recognition and clustering has the challenges for age-wise observation for the capillaries size and shape. [5].

Imaging of the human microcirculation has been limited to vascular beds in which the vessels are visible and close to the surface (for example, nailfold, and conjunctiva).

Mariusz Paradowski et al. calculates avascular area to detect the abnormality in nailfold capillaries. Pattern recognition (histogram analysis and classification algorithm) is used to identify the abnormalities in the vascular capillaries. The segmented capillaries are used to extract the features from the frames of the nail fold video, which is fed for classifier. Doshi proposed a computerized binarisation technique to analyze NC images. It extracts the skeletons of the capillaries by Difference-of-Gaussian approach and thresholding. Then, Post-processing step removes smaller image artefacts [6].

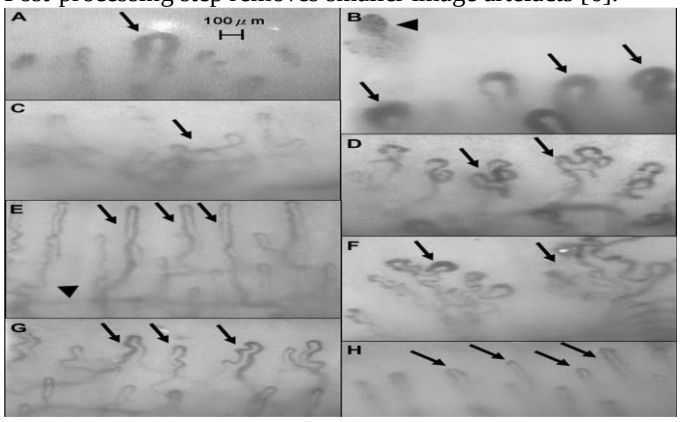

Fig: Nail fold capillaroscopic scleroderma patterns.
Arrow indication: (A) Early pattern: few giant capillaries (B) active pattern-frequent giant capillaries with capillary hemorrhage; (C) late pattern-absent giant capillaries and hemorrhages, severe loss of capillaries with neoangiogenesis(arrow); (D) "bushy" capillaries, twisted enlarged capillaries; (E) long capillary loops with venular visibility (arrow head); (F) Mixed CTD pattern; (G) nonspecific capillary abnormalities; (H) normal pattern-hairpin capillaries, arranged in a parallel fashion to each other

Table-1: Capillaries abnormalities comparisons

Disease	Year and author	Capillary width	Capillary density	Mean value	Sensitivity	specificity	Methods used	Abnormalities
RP [13]	2003,Maurizio cutolo	3.7 (2 – 4.6)	7.7 (5.6 – 10.3)	P<0.01	76.9 %	90.9 %	Image contrast adjustment, magnification	Loss of capillaries, loop features >50 µm & avascular areas
CTD adults	2003, Dolezalova	-	4.8 (2.1-7.8)	P<0.001	-	-	Features are measured manually	Giant capillaries are identified by Loop width=25-50 µm
CTD children	2003, Dolezalova	8.1 (2.6-27.0)	-	P<0.01	-	-	manual measuring , image enhancing	Giant capillaries
DED	2012, Mark Hou	Blood flow velocity = 514.57 µm/s		P<0.05	-	-	Laplacian & skeleteon algorithm.	Turtousity, loop
SSc	2012, Po-Chang Wu et al	14.9(6.5-23.3)	3.7 (2.5 – 7.6)	P<0.005	89.47 %	80%	Manual measurement	Early, active, late and bushy capillaries
SSc [15]	2010, Kim Hs, Park MK et al			P<0.001	91%	98%	Skeleton & binarisation algorithms	Early, active, late capillary patterns

Cutolo found the correlation of the microvascular abnormalities [11] through three Nailfold patterns: early, active, and late. In each group the age of patients, age at onset, and the duration of RP were investigated and correlated with the different NVC pattern variables.

Usually, medical experts evaluate NC images manually. NC is also commercially available, mainly used to detect CTD, RP, and SSC. The advantages are inexpensive, non-invasive, high sensitivity, good specificity and easy interpretation of the results. Now-a-days researchers propose image-processing methods to recognize the abnormalities of the capillaries [9][13].

Infrared thermography measures skin temperature and not perfusion directly, and it is preferred for surgical and peripheral microvascular applications. Other imaging: photoplethysmography, photoacoustic tomography, hyperspectral imaging, and tissue viability imaging are used for clinical microvascular assessment. Perfusion imaging of the microvessels, provides the potential research challenges in microvascular research.

B. FORENSIC SCIENCE

Variable pressure scanning electron microscopy and atomic force microscopy are useful to study the discrete information from the nail unit with the use of image analysis tools. Drug monitoring or cocaine usage can be detected for forensic cases, which is held back by lack of harmonization and validation of analytical methods. Better comprehension is needed of the possible correlation between drug concentrations in the nail matrix and period of exposure. Neutron activation analysis (NAA) and graphite furnace atomic absorption spectroscopy (AAS) are used for segmental analysis for the presence of arsenic, cadmium, mercury, nickel and thallium, etc., in the nails. Periodic ingestion of arsenic can manifest in tissues with correspondent formation of Aldrich Mees lines on the nails, characterized by white streaks. DNA sequences can be retrieved from all biological tissues including nail and often survive relatively better than other tissues in the post mortem context, which may helps to identify the person. Both fresh and old or degraded nail has been used as a source of both nuclear DNA and mitochondrial DNA.

C. BIO-METRIC

Chaikan uses Nail code to increase the accuracy of fingerprint recognition [6]. CCD camera captures a top-view finger image while the user is touching a fingerprint sensor, and the acquired gray scale image is preprocessed to enhance the edges, the skin furrows, and the nail shape before a bank of oriented-filters filters the image. A square tessellation is applied to create a feature map, called a Nail Code [7], employed in the matching process by employing a Euclidean distance computation. It is in conjunction with fingerprint for multimodal biometric identification accuracy.

Karbhari et al proposed multimodal method [4]. The scanned image is cropped manually for index, middle, ring and little fingers. Gaussian low pass filter is applied, and then converted into binary image by thresholding. Nail is extracted on the basis of orientation-based algorithms to decide Region of Interest (ROI). To improve the quality of the images, enhancement has been done. Wavelet decomposition method is used to extract the nail features: longitudinal ridges & lunula. Pre-processed fingernails decompose using wavelet up to second level. Then, concatenate the both feature in single scale feature using mean operation. The difference in detail level features as well as approximation level feature. The metric level features are fusion and classified by Multi-Layer Perceptron(MLP) with a back propagation learning algorithms. Since the feature may vary as per age group so, but Authors focusing the base level of decomposition and concentrates on knuckles only, this is crucial.

Igor et al, 2010 proposed Nail as a transient metric [9] which has a life-time for two months. Right index finger images were taken on different cameras and time. Preprocessing involves segmenting the nail, color correction; nail plate registration and image size, from the finger images. Active shape model (*ASM*) used for Segmentation requires a set of training images in which segmentation performed manually (contour drawn). Principal Component Analysis (*PCA*) is to find Eigen segmentation contours, with accurate results. Image is resized to 128x128 pixels. Local Binary Patterns (*LBP*) is used due to computational efficiency and capacity to discriminate micro-patterns. So, signature extraction employs uniform *LBP* for describing the nail plate texture. Pre-processed nail plate image is divided into smaller image blocks (like 4 x 4 grid) in size of 32 × 32 pixels to generate 16 blocks. A histogram of the values of LBPu2 is computed for each block. The histogram is composed of 59 bins, 58 of them used for uniform patterns and the last bin for non-uniform ones. The signature is then created by concatenating the 16 histograms, forms a global descriptor of the nail plate. Signature matching uses pattern matching Bayesian classifier and K-means classifier.

Kavitha proposed Fuzzy feature set method [2] to measure the shape of the nail with triangularizaion method to construct triangles. The thumb nail bed image can be captured with the help of special lighting equipment. Nail is extracted by ROI Extraction algorithm. Features for the 4 triangular structures are constructed by distance between minutiae, the angle, the orientation differences are measured. The similarity between template and input finger nail is constructed by the triangle similarities and compares the similarities using Fuzzy Feature method and Back Propogation Network methods, yields the accuracy of 92% and 90% respectively.

Shruthi Garg et al propose nail plate is a new biometric identifier by its texture ad surface appearances [3]. Gabor filtering normalizes the captured image for rotation adjustment, middle, index and ring finger nails as ROI.

Imaging Device	Author/year/ Proposed method	Methods used	Accuracy rate	Merits	demerits
Cannon A630 Digital Camera (1600 x1200)	Shruti Garg et al, 2014 / Nail Plate: new bio-metric	Gabor filtering, ROI, Haar wavelet, ICA	98%	Recognition rate is high when fusion is applied for 2,3 & 4th fingers	-
Camera + lighting equipment	Kavitha jabamalar, 2014 / Nail geometric matching	ROI, FFM, BPN algorithms	92%	Reduces complexity and produces better accuracy in Matching.	The nail fold shadows or fungus may cause mismatching. It doesn't consider additional traits.
HP color laser jet scanner	Karbhari V. Kale et al, 2013 / Multimodal bio-metric	Guassian Low pass filter, threshold wavelet & orientation based segmenting, MLP classifiers	97%	It can works for low resolution images, no special sensors/devices are required.	It gives high accuracy when fusion with other-metrics only.. Fusion at feature level is still an issue
Camera	Igor et al, 2010 / Transient bio-metric	PCA, LBP based segmentation, Bayesian & K-means classifier	99%	It considers nail plate appearance only and complexity is less.	Acceptability is an issue and retrieving nail matrix feature is challengeable
CCD camera+ fingerprint sensor	Chaikan.P, 2007 / Nail code	Linear filter, median fiter, Eucledian distance between 2 points by tesselation	96.57%	Used as additional metric in multi-modal type	Though very simple method, the points should be sticked exactly on the nail plate

Table-2: Comparison of nail plate units in bio-metric articles

Fingers are localized and decomposed to point the nail surface of each fingers. The features are extracted by Haar wavelet HW and Independet Component Analysis ICA methods and the accuracy rates are 76 &81 for index fingers and in fusion are 91.5 &96.5 respectively. The overall fusion method for three fingers it gives 98% accuracy

IV. CONCLUSION

In Medical Imaging, plenty of research findings are published but lots of research areas are still untouched. This paper addresses the challenges and research issues which relate to nail unit.

REFERENCES

[1] Pragnesh Parmar, Gunvanti B. Rathod," Forensic Onychology: An Essential Entity against Crime", *J Indian Acad Forensic Med. October-December 2012, Vol. 34, No. 4* ISSN 0971-0973, pp-355-357

[2] Kavitha Jaba Malar R, Joseph Raj V,"1 Geometric Finger Nail Matching using FuzzyMeasures",IJITEE, ISSN: 2278-3075, Volume-4 Issue-4, September 2014

[3] Shruti Garg, Amioy Kumar, and M. Hanmandlu,"Finger Nail Plate: A New Biometric Identifier" IJCISIM,2014, pp. 126 – 138

[4] Karbhari V. Kale, Yogesh Rode, Majharoddin M. Kazi, Shrinivas Chavan, and Siddharth Dabhade and Prapti Deshmukh,"Multimodal Biometric System Using Finger Knuckle and Nail: A Neural Network Approach", International Journal of Electrical Energy, Vol. 1, No. 4, 2013, pp.222-227

[5] Mark C. Hou · Sheng-Chieh Huang · Hui-Min Wang, "A computerized system of nail-fold capillaroscopy for dry eye disease diagnosis", Feb 2012, Springer plus, Multidim Syst Sign Process (2012) pp:515–524

[6] Doshi, N.P., Schaefer, G. ; Shao Ying Zhu," An Improved Binarisation Algorithm for Nailfold Capillary Skeleton Extraction",2013, IEEEXplore, SMC, pg. 2565 – 2569

[7] Chaikan P, Songkhla ; Karnjanadecha, M. The Use of Top-View Finger Image for Personal Identification Image and Signal Processing and Analysis, 2007. ISPA 2007. 5th International Symposium on 2007, pg: 343 - 346

[8] *Ximena Wortsman* "Common Applications of Dermatologic Sonography,", J Ultrasound Med 2012,31:97–111

[9] Igor Barros Barbos,a Theoharis Theoharis, Christian Schellewald & Cham Athwal,"Transient Biometrics using Finger Nails",2010,

[10] Stamatis Gregoriou, George Argyriou, George Larios, Dimitris Rigopoulos, "Nail disorders and systemic disease: What the nails tell us" J Fam Pract. 2008 August;57(8):509-514.

[11] M.Cutolo, M.Matucci Cerinic, "Nailfold Capillaroscopy and classification criteria for systemic sclerosis", Clinical and Experimental Rheumatology 2007, pp. 663-665

[12] P Dolezalova, S P Young, P A Bacon, T R Southwood, "Nailfold capillary microscopy in healthy children and in childhood rheumatic diseases: a prospective single blind observational study", Ann Rheum Dis 2003;62:444–449

[13] Lambova S, Müller-Ladner U.,"Capillaroscopic pattern inparaneoplastic Raynaud's phenomenon" Rheumatol Int. 2013 Jun;33(6):1597-9

[14] *Robert Baran, Rodney PR Dawber, Eckart Haneke, Antonella Tosti, Ivan Bristow, &*Luc Thomas*,,"*A Text Atlas of Nail Disorders Techniques in Investigation and Diagnosi", third edition, Martin Dunitz, Taylor & Francis group.

[15] Kim HS[1], Park MK, Kim HY, Park SH." Capillary dimension measured by computer-based digitalized image correlated with plasma endothelin-1 levels in patients with systemic sclerosis"Clin Rheumatol. 2010 Mar;29(3):247-54

[16] Wu PC, Huang MN, Kuo YM, Hsieh SC, Yu C,". Clinical applicability of quantitative nailfold capillaroscopy in differential diagnosis of connective tissue diseases with Raynaud's phenomenon", J Formos Med Assoc. 2013 Aug;112(8):482-8.