The mitral valve and mitral regurgitation

The mitral valve is located between the LA and the LV and is composed of two flaps,\(^3\) as shown in Figure 1.

During systole or LV contraction, the flaps are tightly closed, but in patients suffering from mitral valve prolapse, the valve flaps get enlarged and stretch inward into the LA. During systole, the mitral valve sometimes “snaps” allowing some blood to flow back into the LA and it is called regurgitation.\(^4\)

Because of this leak, the heart pumps lesser blood to remaining parts of the body. This leak has no significance in case of mild MR; however, in cases of moderate or severe MR, to compensate for the leak, the LV exerts itself more to supply blood to other parts of the body. In due course, depending on the volume of blood that is regurgitated, the heart muscle and the circulatory system undergo a series of changes resulting in cardiovascular morbidity and mortality.\(^5\)

Color Doppler echocardiography

Accurate assessment of MR severity is crucial for making decisions regarding surgery, predicting prognosis, clinical decision-making, and for optimizing patient outcomes.\(^6\) Color flow Doppler is the most preferred technique to detect and evaluate MR as shown in Figure 2.\(^7\)

The backflow of blood into the LA from the LV through the mitral valve is displayed in the form of the jet by color Doppler echocardiogram, as shown in Figure 3. MR is visually diagnosed through apical two-chamber and apical four-chamber views, and regurgitation jets are often represented in plain blue hues or high-saturation color mosaics comprising blue, yellow, and orange hues.\(^8\) The region above the regurgitation orifice, where the blood converges to enter the LA though the orifice, is called flow convergence zone and the size of the orifice corresponds to the width of the orifice and volume of the blood flow. The blood enters the LA through a narrow orifice, and here, the velocity of the blood is the highest and this region is called “vena contracta.” The width of the “vena contracta” gives an insight to estimate the severity of MR, and it is directly proportional to the width of the regurgitation orifice. The portion of the jet that is seen in the LA is the “jet body.” The area and length of the jet body also correspond to the severity of MR.\(^9\)

To detect and extract the jet area for grading the MR, color segmentation using K-means clustering with histograms in hue-saturation-value color space is proposed.\(^10\) To acquire better color representation, the color histogram bins and gray histogram bins are separated.\(^11\)

In this work, color Doppler echocardiogram images are used to classify MR into three different categories, namely mild, moderate, and severe. For this, first, the jet region is segmented from the color Doppler images using our earlier proposed methodology\(^12\) and using the segmented jet area, parameters, such as jet area perimeter, shape index, stroke volume (SV), and ejection fraction, are calculated. The calculated parameters are classified using backpropagation neural network (BPNN) and support
vector machine (SVM) classifier to evaluate the severity of the MR as mild, moderate, or severe.

**Proposed Methodology**

The block diagram of the proposed system is shown in Figure 3.

**Segmentation of the jet area by K-means clustering**

To start with the proposed method the color Doppler echocardiogram video is converted into frames, and the artifacts such as labels and wedges present in the image are eliminated as they may hinder the segmentation process. As we are interested only in the region containing the heart, the rectangular region of interest (ROI) that is the region containing the heart alone is selected by cropping the image using the value (135 105 775, 575) where (135,105) represents the top left (x, y) coordinates of the ROI triangle and 775 is the height and 575 is the width of the rectangle containing the heart region in the echocardiogram image. These values were arrived at, after empirically in our previous work,[12] after analyzing a number of color Doppler echo images. This rectangular region in each frame is then segmented using K-means clustering, and the mosaic pattern corresponding to the regurgitant jet is extracted using thresholding. The extracted mosaic pattern from all the frames is converted back to video for the convenience of a clinician.

Figure 4 shows the ROI to be removed, i.e. artifact removal and the jet area to be segmented. In the case of color Doppler with MR disease, a mosaic pattern represents the regurgitated blood which is the MR jet area to be segmented. K-means clustering is used to segment jet area.

K-means clustering is an unsupervised classifier, which classifies the features into K number of clusters, where K is a positive integer.[13] Clustering is done by minimizing Euclidean distance between data and corresponding cluster centroids. Then, the segmented region is converted to grayscale image, and since the pixel value of the jet area to be segmented lies between 240 and 250, the threshold is applied to extract the jet area alone. Sample frames and corresponding segmented regions are shown in Figure 4. Then, the frames containing the segmented jet area are converted back into video to help the clinicians to visualize the MR jet. Table 1 shows the comparison of jet area calculated by echocardiographer and the automatically segmented jet area by the proposed method. From Table 1, it could be seen that the difference of the manually segmented and the automatically segmented jet area is minimal and acceptable. The proposed method almost satisfies the clinical results and could be effectively employed to segment MR jet region in color Doppler echo images.

Then, from the segmented jet region, parameters such as volume, area, and jet area ejection fraction are calculated. Furthermore, shape features, namely perimeter and shape index are calculated to improve the diagnostic accuracy.

**Extraction of jet area parameters**

The volume of the jet area can be calculated as follows:

\[
\text{Volume} = \frac{7.0}{2.4 + D^3}
\]  

(1)

Where “D” is the equivalent diameter.

The largest jet area volume (LJAV) and the smallest jet area volume in a cardiac cycle are calculated from the segmented jet area. The difference between them gives the SV, i.e., LJAV–LJSV, and the ratio of SV to the LJAV gives the EF, i.e., the amount of blood regurgitated and is given by:

\[
\text{JAEF} = \frac{\text{LJAV} - \text{LJSV}}{\text{LJAV}}
\]  

(2)

JAEF can be used by the cardiologist to determine the severity of the MR.

**Table 1: Comparison of jet area segmented manually by a cardiologist and with the proposed method**

| Sample frame number | Jet area segmented automatically JA (pixels) | Jet area segmented manually JC (pixels) | Difference | JA-JC | (pixels) |
|---------------------|--------------------------------------------|----------------------------------------|------------|-------|---------|
| 1                   | 4670                                       | 5144                                   | 474        |       |         |
| 2                   | 1271                                       | 1178                                   | 93         |       |         |
| 3                   | 2324                                       | 2456                                   | 132        |       |         |
| 4                   | 1302                                       | 1289                                   | 13         |       |         |

JA- Jet area segmented automatically, JC - Jet area segmented manually
Extraction of shape features
Since the severity depends on JAV, the shape features\textsuperscript{[14]} are calculated from the segmented jet area with the largest volume in such a way, an average of each shape feature is calculated from LJAV frame to LJSV frame and a feature vector is formed. The LV shape index is sensitive to deviation of shape from a circular one and it depends on area and perimeter of the jet area boundary. The shape index is calculated as follows:

\[ \text{LV Shape Index} = \frac{4\pi(Area)}{(Perimeter)^2} \]  \hspace{1cm} (3)

The other shape features such as area, perimeter, equivalent diameter, minor axis length, major axis length, solidity, and eccentricity of the segmented area are also calculated. Calculating the distance between each adjoining pair of pixels around the border of the jet area region gives the perimeter.

Classification
The extracted jet area parameters such as JAV, jet area ejection fraction along with the shape feature area, perimeter, equivalent diameter, minor axis length, major axis length, solidity, and eccentricity are then fed to the SVM and BPNN classifier for classifying the condition as mild MR, moderate MR, and severe MR. The literature reveals that SVM and BPNN classifiers give excellent classification performance in medical image analysis, and as such, they are chosen to grade MR in this work.

The BPNN consists of an input layer, one or more hidden layers, and an output layer. BPNN learns from the training samples presented in the input layer. The input data navigate through the hidden layers which are multiplied with predefined weights, and the results are produced at the output layer. The results obtained are compared with the desired output, and the difference between the two is the error, which is then propagated backward through the network to the input layer. As the error is propagated backward, the weights connecting the neurons are adjusted by the backpropagation algorithm. The process is repeated until the desired output is obtained or the error is negligible. BPNN is elaborately discussed.\textsuperscript{[15]}

SVM is a supervised learning algorithm, for two classification problems in the simplest form. The principle of SVM is to find the hyperplane and the support vectors, which are samples that lie on or near the hyperplane. The hyperplane is chosen in such a way that the distance between the two classes is maximized, which helps SVM to model the two different classes from the training samples. SVM easily classifies linearly separable samples; however, when the samples are linearly inseparable, then the kernel functions such as Gaussian radial basis function, polynomial (inhomogeneous), polynomial (homogeneous), and sigmoid kernel could be used to separate the two classes. An intuitive explanation of SVM is given.\textsuperscript{[16]}

Results and Discussion
A database of 70 Doppler echocardiogram videos with MR disease (20 – mild, 30 – moderate, and 20 – severe) videos acquired using Philips iE33 xMATRIX echo system from the division of cardiology, Raja Muthiah Medical College Hospital, Annamalai University, is used for this study. Each video is up to 2 s having 26 frames/s.

The echocardiogram video or sequence is given as input to the proposed system, and the jet area is segmented using color-based segmentation using K-means clustering algorithm. Sample frames and corresponding segmented regions are shown in Figure 5.

From the segmented jet region parameters such as volume, area, and jet area ejection fraction are calculated. Furthermore, shape features such as perimeter, equivalent diameter, minor axis length, major axis length, solidity, and eccentricity of the segmented area are calculated. The extracted features are fed to BPNN classifier and in this work; the number of neurons in the input layer is nine. The hidden layer neurons are fixed to 50 after empirically analyzing the count. The output layer consists of three neurons which are nothing, but the MR severity grades mild, moderate, and severe. The features are also fed to the SVM classifier for classifying MR into any of the three classes, and for this, the radial basis function kernel of SVM is used.

![Figure 5: (a) Original frames extracted and (b) segmented jet area](image-url)
The performance of BPNN and SVM classifier in grading mitral valve regurgitation is given in Table 2. From the table, it could be seen that SVM with an accuracy of 90%, sensitivity of 85.1%, and specificity of 92.31% outperformed BPNN in correctly classifying the MR into mild, moderate, and severe.

**Conclusion**

In this article, an alternate method to PISA to automatically quantify mitral valve regurgitation severity was proposed. This method employs K-means clustering algorithm to perform color-based segmentation of the regurgitant jet region. From the segmented region, jet area parameters and shape parameters were extracted, which were modeled using SVM and BPNN classifiers to quantity the MR severity into mild, moderate, and severe. The results obtained indicate that the proposed work could be used as an alternative method to assess the severity of mitral valve regurgitation.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Zoghbi WA, Adams D, Bonow RO, Enriquez-Sarano M, Foster E, Grayburn PA, et al. Recommendations for noninvasive evaluation of native valvular regurgitation: A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017;30:303-71.
2. Sankar V, Roy TN, Venugopal KN. Angle correction for proximal isovelocity surface area method: Is it spheric cap or lune? J Am Soc Echocardiogr 2006;19:241.
3. Chopra HK, Nanda NC. Textbook of Cardiology: A Clinical & Historical Perspective. 1st ed. New Delhi, India: Jaypee Brothers Medical Publishers; 2013.
4. Lancellotti P, Moura L, Pierard LA, Agricola E, Popescu BA, Tribouilloy C, et al. European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 2: Mitral and tricuspid regurgitation (native valve disease). Eur J Echocardiogr 2010;11:307-32.
5. Mantovani F, Clavel MA, Michelena HI, Suri RM, Scafﬁ HV, Enriquez-Sarano M, et al. Comprehensive imaging in women with organic mitral regurgitation: Implications for clinical outcome. JACC Cardiovasc Imaging 2016;9:388-96.
6. McCarthy KP, Ring L, Rana BS. Anatomy of the mitral valve: Understanding the mitral valve complex in mitral regurgitation. Eur J Echocardiogr 2010;11:i3-9.
7. Thomas JD, Liu CM, Flachskampf FA, O'Shea JP, Davidoff R, Weyman AE, et al. Quantification of jet flow by momentum analysis. An in vitro color Doppler flow study. Circulation 1990;81:247-59.
8. Anderson B. Doppler quantification of regurgitant lesions. Echocardiography: The Normal Examination and Echocardiographic Measurements. 2nd ed., Ch. 13. Australia: MGA Graphics; 2007. p. 336.
9. Biner S, Rafique A, Rafii F, Tolstrup K, Noorani O, Shiota T, et al. Reproducibility of proximal isovelocity surface area, vena contracta, and regurgitant jet area for assessment of mitral regurgitation severity. JACC Cardiovasc Imaging 2010;3:235-43.
10. Chen TW, Chen YL, Chien SY. Fast image segmentation based on K-Means clustering with histograms in HSV color space. In: Multimedia Signal Processing, 2008 IEEE 10th Workshop on. IEEE; 2008. p. 322-5.
11. Elomaa T, Koivistoinen H. On autonomous k-means clustering. In: Proceedings of 15th International Symposium on Methodologies for Intelligent Systems; 2005. p. 228-36.
12. Balaji GN, Subashini TS, Chidambaram N. Automatic detection of mitral regurgitant jet by K-means clustering. Int J Appl Eng Res 2014;9:4600-4.
13. Aggarwal CC, Reddy CK. Data Clustering: Algorithms and Applications. 1st ed. New York: Chapman and Hall/CRC Press; 2013.
14. Nixon M, Aguado AS. Feature Extraction & Image Processing. 2nd ed. UK: Academic Press; 2008.
15. Haykin S. Neural Networks and Learning Machines. 3rd ed. USA: Pearson; 2008.
16. Cristianini N, Shawe-Taylor J. An Introduction to Support Vector Machines and Other Kernel-based Learning Methods. 1st ed. UK: Cambridge University Press; 2000.
Perspective

Decoding increasing prevalence of noncommunicable diseases

Alok KS Thakur
Centre for Holistic Health, Dehradun, Uttarakhand, India

ABSTRACT

Background: In recent times, noncommunicable diseases (NCDs) have attained epidemic status in India and several other countries. Globally, each year, NCDs cause premature deaths of nearly 40 million people younger than 60 years accounting for 70% of all deaths; 80% of these premature deaths are reportedly in the low- and middle-income countries. Many studies have reported increasing prevalence of NCDs such as type 2 diabetes, coronary and pulmonary diseases, and cancer. Incidentally, all these studies besides discussing environmental pollution have grossly ignored dietary profiling of affected populace despite the fact that several studies have established a direct correlation between food quality and good health.

Objective: Besides pollutants, an attempt is made to analyze mathematically effects of dietary changes over the last four decades on constantly increasing prevalence of NCDs at cellular level. A relationship seems to exist between increasing prevalence of NCD and large-scale consumption of synthetic salt.

Conclusions: Elimination of essential trace elements and micro- and macro-minerals in regular diet through synthetic salt fortified with iodine alone appears to cause more harm than benefits associated with iodization of salt than pollutants. Regular intake of essential trace elements is necessary for normal functioning of many fundamental functions of the body such as Na-K pump, electron–proton transport, biochemistry, and thermodynamics. An attempt has been made to study effects of salt constituents used in food at the most fundamental cellular level by means of disturbances in body electrolyte through heat and ion transport mechanism that is fundamental to various underlying processes in human body. Interestingly, almost all the families who switched over to unprocessed rock salt from synthetic iodized salt reported improvement in general health and reported reduction in medical visits.

Keywords: Himalayan salt, iodine deficiency disorder, iodine-induced hyperthyroidism, iodized salt, ion transport mechanism, Na/K pump, noncommunicable disease, proton pump, sea salt

Introduction

From time immortal, human beings are dependent upon natural sources of water such as springs, lakes, and rivers rich in micro- and macro-nutrients as well as natural salt obtained from lakes, sea, or rocks containing large number of essential trace elements and micro- and macro-minerals. This natural dependence has played decisive role in the biological evolution of the human body. In the last 6–7 decades, there have been large-scale changes in dietary pattern, and large section of global population has moved from natural water to processed water and natural salt to iodized salt for various reasons. This dietary move has deprived the population from daily regular intake of trace elements and micro- and macro-nutrients.

Greater understanding of human physiology and advances in medicine appears to be of little help in controlling growing and spreading various noncommunicable diseases (NCDs) such as type 2 diabetes, hypertension, hyperacidity, coronary deceases such as cardiovascular, angina pectoris, aortic stenosis, heart valve malfunction,
atrial fibrillation, gallstone pancreatitis, or renal deceases such as calculi, hypercalcemia, IgA nephropathy, eye disorders and cancer that were earlier attacking middle age onwards have started attacking at pediatric stage at an alarming rate. Every year, NCDs are responsible for premature deaths of 40 million people younger than 60 years accounting for 70% of all deaths globally; 80% of these premature deaths are in the low- and middle-income countries.

As per the American Cancer Society, childhood cancer incidence rates have slowly increased by 0.6% per year since 1975 and estimated 10,380 new cases in 2016 with 1,250 deaths. However, advances in treatment brought down death rate to almost 66% from 1969. Similarly, about 1,685,210 Americans were expected to be diagnosed with new cancer cases in 2016 with about 595,690 deaths that translate to about 1,630 deaths per day. Cancer is the second most common cause of death in the US, exceeded only by heart diseases, and accounts for nearly 1 of every 4 deaths. Congenital anomalies and reproductive system disorders such as endometriosis, sperm disorders, and birth defects are also slowly but surely reaching epidemic stage. Besides several external factors such as tobacco, alcohol, infectious organism, and inherited genetic mutations responsible for increasing prevalence in NCDs, “unhealthy diet” appears to be more prominent.[1]

Among NCDs, we have chosen type 2 diabetes for the sake of study and discussion; the same discussion goes very well for other NCDs as well because it is based on fundamental processes of human body.

Type 2 diabetes is one of the most debated ailments across the world with global prevalence estimate of 108 million in 1980 to projection of 422 million in 2014 a whopping growth rate of 390% over a period of just 34 years.[2] Viner et al.[3] and McGavock[4] have associated diabetes in adolescents with poverty. Poverty is an important factor but not the sole cause for the prevalence of the disease. There are other factors too which are seriously responsible for diabetes and NCD in the developing countries such as India. In 2017, the World Health Organization (WHO) has related 61% of deaths to NCDs in India; globally, it is 70%.[3]

Observations and data
Several studies have been made on the prevalence of type 2 diabetes in India and other countries. The most recent study named ICMR-INDIAB by the government’s Indian Council of Medical Research (ICMR) covering 15 states widely geographically distributed in India and published in the Lancet Journal of Diabetes and Endocrinology in August 2017; Table 1 shows the prevalence verses per capita gross domestic product (GDP).[6]

As evident in Table 1 of the ICMR study, Indian states with higher GDP have been found to have a higher prevalence of type 2 diabetes.

In rural area of all participant states, type 2 diabetes is more prevalent in individuals of higher socioeconomic status (SES). The populace with lower SES are still dependent upon raw sea salt on account of fraction of price compared to iodized salt and are incidentally free from type 2 diabetes. Although there is an official ban on sale of cheaper raw sea salt for human consumption, it is available for animals and thus used by poor rural populace on account of economic considerations.

On the other hand, urban areas of some affluent states such as Chandigarh, Maharashtra, and Tamil Nadu show a higher prevalence of type 2 diabetes in people with even lower SES populace; it means that economically disadvantaged strata of society are found to be more vulnerable to type 2 diabetes and other NCDs. This is due to nonavailability of cheaper raw sea salt, on account of official ban on raw sea salt for human consumption, leading to forced dependence on iodized salt, thus making poor populace starve of essential trace elements and micro- and macro-minerals available in raw sea salt who are already devoid of balanced diet.

This is very valuable statistical data,[4] and a deeper insight reveals the cause of prevalence as well but has been missed by the authors inadvertently.[6] The study has totally missed

| Indian States | GDP per capita (US$) | Prevalence of diabetes |
|--------------|---------------------|------------------------|
| Bihar        | 682                 | 4.3                    |
| Manipur      | 909                 | 5.1                    |
| Assam        | 968                 | 5.5                    |
| Jharkhand    | 1009                | 5.3                    |
| Meghalaya    | 1346                | 4.5                    |
| Tripura      | 1525                | 9.4                    |
| Mizoram      | 1665                | 5.8                    |
| Andhra Pradesh | 1780            | 8.4                    |
| Arunachal Pradesh | 1870   | 5.1                    |
| Karnataka    | 1959                | 7.5                    |
| Punjab       | 2020                | 10                     |
| Gujarat      | 2337                | 7.1                    |
| Tamil Nadu   | 2464                | 10.4                   |
| Maharashtra  | 2561                | 8.4                    |
| Chandigarh   | 3433                | 13.6                   |

GDP: Gross domestic product
to correlate important changes in dietary intake with diabetes prevalence.

Broad dietary pattern of Indian rural and urban populace can be tabulated in Table 2.

We would like to supplement reasons for type 2 diabetes increasing prevalence. Before the early 1970s, only handful of urban families had a history of type 2 diabetes, this was the period when everyone was dependent upon raw sea salt crystals in regular cooking, and Himalayan salt was only used, being expensive, during Hindu fasting days. Both salts contained >80 micro- and macro-minerals and trace elements.[7] There was no iodized salt in the market during that time frame.

Let us go back a little historically. The populace in some geographical areas were suffering with goiter. To counter iodine deficiency and thyroid disorders, the Government of India undertook salt iodization program in the 1950s. Encouraged with the positive results on goiter control, the Government of India launched the National Goiter Control Programme in 1962 assisted by the WHO and UNICEF with total annual installed capacity of 0.385 million tons. One of the objectives of the program was to supply iodized salt in place of common salt (sea salt) to all the identified and notified goiter endemic areas in the country. Early iodized salt production could not meet the requirement of all endemic areas till 1983 when private sector was also roped in to promote production of iodized salt. Although the iodized salt was meant to be for goiter endemic area, subsequently in 1998, it was made mandatory across the board through a ban on human consumption of natural sea salt. The ban was lifted for some time in 2000 after widespread protests and re-imposed in 2005[8] without any authentic study on the impact of widespread iodized salt consumption even in nonendemic area. The last 50 years of state-sponsored program on forced consumption of iodized salt could not eliminate occasional limited prevalence of thyroid disorder and rather it has attained epidemic status along with other NCDs. Today, it is hard to find a family where thyroid patients are not available; in fact, the populace have embraced it as a lifestyle disorder and do not mind a popping up a little thyroxin tablet every morning.

The prevalence of type 2 diabetes in urban Indians has steadily increased from 2.1% in the 1970s to 8.2% in the 1980s, later climbing to 12%–16%. India now leads the world with 40.9 million people in type 2 diabetes in 2007. Moreover, it is projected that, by the year 2025, 80.9 million Indians will have type 2 diabetes. The phenomenon of high prevalence of type 2 diabetes spreads to urban India and is rapidly moving to rural areas as well.[9] Interestingly, this is the period when thyroid disorders have also shown almost the same growth pattern despite forcing the public to adopt iodized salt through a government ban on raw sea salt. A Sri Lankan study has found a close relationship between consumption of iodized salt and the serum thyroid-stimulating hormone (TSH) levels.[10,11]

In India, agriculture is one of the traditional activities in rural areas, and still, in the digital age and rapid mechanization, it remains labor intensive where majority of farmers plough their fields with bullocks. Surprisingly, despite no genetic history of type 2 diabetes, these remote rural folks are slowly but steadily falling prey to type 2 diabetes despite their lifestyle is far from sedentary that is attributed for its prevalence as compared to urban folks. Interestingly, type 2 diabetes, obesity, and thyroid disorders in urban folks are almost catching up with white collar and blue collar, rich and hard working poor with the same vigor. Even fisherman both sweet water and coastal whose staple diet is fish and seafood, rich in iodine, are untouched from diabetes. Similarly, vegetarian and nonvegetarians populace are suffering alike in this matter.

### Discussion

The above widespread observations compel one to reason out why such vast spectrum society has started suffering from thyroid and type 2 diabetes disorders despite the fact that upper strata of society being rich and health conscious manage balanced diets and health supplements. It means there is something very seriously wrong in daily food intake that is very common among rural as well as

| Table 2: Dietary pattern vs diabetes |
|-------------------------------------|
| **Populace** | **Vegetables intake** | **Fruits and dairy intake** | **Iodized salt intake** | **Sea salt intake** | **Diabetes cases** |
| Deep rural (A) | Occasional | Rare | Never | Always | None reported* |
| Deep rural (B) | Occasional | Rare | 2%-5% population | Rest | Low |
| Urban poor | Occasional/daily | Occasional | 90%-95% | 10%-5% | Higher |
| Urban rich | Daily | Daily | 100% | 0% | Very high |

*This may be due to poor health facilities and awareness available in deep rural areas. A: Indian villages far from city and devoid of modern amenities and iodized salt, B: Indian villages nearer to city, some homes with modern amenities.
urban folks, rich and poor, and has been changed in recent times. Further, this “change” is part of staple diet of urban and rural populace alike despite a huge variation in food habits and food preparations which is known to vary every 20 km or so and neighborhood to neighborhood. In Indian scenario, type 2 diabetes first caught the urban-rich populace and then reaching to urban poor. Now, the rural populace also follow the qualitative consumption pattern of iodized salt and its adoption from urban to rural.

Manufacturing of iodized salt removes micro- and macro-minerals and trace elements from sea salt and rock salt that contribute about 14% by weight. These micro- and macro-minerals and trace elements are removed from the regular diet and substituted with pure sodium chloride. This large substitution of essential minerals and trace metals by NaCl causes major changes in electrolyte composition leading to impairment of various fundamental processes in the human body such as functioning of Na-K pump, calcium pump, and various thermodynamic and biological functions of the body system that are largely dependent on the concentration of various components.

Functional impairment of various body systems has been attempted on the basis of principles of physics. For example, heat and mass transfer across the cell changes drastically with changes in electrolyte composition causing impairment of neuron conduction in nerve cells. Heat movement in human cell can be illustrated by the following differential heat conduction equation:[12]

$$\frac{\partial}{\partial t}[K(x,t)\frac{\partial \theta(x,t)}{\partial x}] = \rho(x,t)C(x,t)\frac{\partial \theta(x,t)}{\partial t}$$  \hspace{1cm} (1)

where \(K(x,t)\) is space- and time-dependent thermal conductivity of cell internal fluid.

\(\rho(x,t)\) is space- and time-dependent density of cell internal fluid.

\(C(x,t)\) is space- and time-dependent specific heat of cell internal fluid.

\(\theta(x,t)\) is temperature of cell internal fluid at any instant \(t\) and position \(x\).

It is evident from the above mathematical formulation that thermodynamics of whole body changes with change in concentration of cell internal fluid \(\rho(x,t)\) and composition of body electrolytes leading to changes in specific heat \(C(x,t)\) and thermal conductivity \(K(x,t)\). These physical changes are responsible for malfunctioning of various fundamental body processes such as Na\(^+\)/K\(^+\) pump, thereby causing malfunction of glands and body organs with manifestation of many diseases such as type 2 diabetes and other NCDs.

Similarly, transport mechanism of main electrolyte ions Na\(^+\) and K\(^+\) within nerve cell can be formulated as below:[13]

$$J_{Na^+} = D_{Na^+} \nabla Na^+ + Na^+ \mu_{Na^+} E$$  \hspace{1cm} (2)

$$\frac{\partial Na^+}{\partial t} = -\nabla J_{Na^+}$$  \hspace{1cm} (3)

$$J_{K^+} = D_{K^+} \nabla K^+ + K^+ \mu_{K^+} E$$  \hspace{1cm} (4)

$$\frac{\partial K^+}{\partial t} = -\nabla J_{K^+}$$  \hspace{1cm} (5)

Where

Na\(^+\) and K\(^+\) are concentration of sodium and potassium ions in the nerve cell, respectively.

\(q\) is elementary charge on the sodium and potassium ions, respectively.

\(J_{Na^+}\) and \(J_{K^+}\) are electric currents due to sodium and potassium ions in the nerve cell, respectively

\(E\) is the electric vector.

\(\mu_{Na^+}\) and \(\mu_{K^+}\) are mobility of Na and K ions, respectively.

\(\nabla Na^+\) and \(\nabla K^+\) are concentration gradients of Na\(^+\) and K\(^+\) ions within nerve cell, respectively. \(\nabla\) represents divergence and \(t\) is the time at any instant.

Equations (1) through (5) clearly show effects of changes in electrolyte composition on performance of Na\(^+\)/K\(^+\) pump. Performance degradation of Na\(^+\)/K\(^+\) pump disturbs transmission of brain neuron signals which produce an electrical spike called action potential (AP). After an AP, the Na\(^+\)/K\(^+\) pump resets the arrangement of Na\(^+\) and K\(^+\) ions back to their original positions so that the neuron is then ready to relay another AP when it is called upon to do so. Hence, the Na\(^+\)/K\(^+\) pump has a “housekeeping” role rather than a direct role in brain signaling; this is the long-held, entrenched viewpoint.[14,15] However, novel research upon cerebellar Purkinje neurons suggests that the Na\(^+\)/K\(^+\) pump may have a direct role in brain coding and computation.[16]