Derivation of mechanobiological factors for home arterial blood pressure and pulse rate.

Abstract

Background: Blood pressure measurement is routine in clinical setting and this can easily be done in out-of-office setting. The collection of data especially through health apps has the potential to improve clinical management. However, little is known known about implementation, regularization of operation that is meaningful to identify evolving clinical state, adopt personalized intervention through shared decision and improve strategy to understand blood pressure dynamics in its evolution in a natural setting. It is very imperative in this process to avoid disruption in regular workflow, identify difficulties in data processing, expand accessibility to filtered incoming information and identify features needed to support clinical team before interfacing validated components with integrated data panels in the electronic medical record.

Objective: The initiative of this undertaking was originally aimed to create technically simple means to collect blood pressure and blood sugar data referred here as patient generated biometric data, (PGBMD) from the customers directly, or indirectly, collaborate with customers, allied health services (Coaches, dietitian) and clinical team. Our objective was to facilitate every patient with uniform access to comprehensive data to integrate supporting activities seamlessly in the management of patients with cardio-metabolic disorder in its various stages (BP, Pulse, Weight, medication and laboratory data).

Method: This implementation was undertaken in an independent clinic designed to collect multiple parameters such as; raw blood pressure, pulse, blood sugar weight and temperature. The development of technical aspect of the design in its initial stages, critically focused to prioritize customer's need, literacy, limitation and supporting alternative scheme necessary for sustainable activation information exchange and customer participation. From provider perspective, we explored work flow factors, data visualization, technical design for interaction, expose hidden components on incoming data and interface interpretable panel information on complex disease syndrome critical to understand significance and decrease burden on clinical care givers in data collection and integration.

Result: We are able to show PGBMD can be a part of work flow, provide robust information for virtual interaction and helps monitoring characterization of disease by stages and enable intervention by qualified stakeholders (health coaches, dietitian, behavioral scientist and exercise physiologist) in some disease conditions. In the description that follows we have limited our discussion to distinctive components derived in this scheme such as aggregates on BP and pulse, analysis of component on repeated blood pressure and pulse and its potential to understand effective intervention sectors in a clinical setting.

Summary: PGHMD can help clinician to understand customer's need. Implementation routine operation, to collect and integrate in blood pressure and pulse data in clinical practice for virtual interaction on certain disease conditions is practical. This process can improve our understanding on momentary issues and patient's needs in conditions without any symptoms. Repeated collection of blood pressure and pulse readings can improve clinical decision and expand

knowledge on hitherto, missed components on blood pressure and pulse. This process by and large, also supports allied health care collaboration and prioritize aligning with other stakeholders meaningful for health care intervention in orderly sequence in the management of cardiometabolic disorders.

Introduction.

Background and objectives: Hypertension play a key role in the development and progression of cardiovascular complications (Lewington). For more than a century, across the globe, defining systolic and diastolic blood pressures and the management of hypertension are done in the clinics. In this system level operation, the quality and number of clinic blood pressure measurement have always been a limiting factor. The measurement of blood pressure out of the office is easy and can be reliably done using affordable device. The collection of large number these out-of-office BP observations permit better estimate of blood pressure values.

In hypertension the level of risk for a long time is known to evolve with linear progression in blood pressure above 110 mmHg systolic blood pressure (Lewington, Rapsomaniki, Wang). This early change is also associated with functional and structural changes in the organs (Kramer, Nuotio, Olesen). The majority of population at risk for cardiovascular adverse events happens to be between 110 to 140 mm systolic blood pressure (Tajeu). The supporting evidence for this comes from a large population group where the background for quality of blood pressure collection was not uniform. In the above context there has been several societies have aligned to set guidelines and goals.

The most recent goal-setting recommended to grade clinic blood pressure control comes with a gap between ACC/AHA and ESC/ESH recommendation. The threshold for diagnosis of hypertension for ACC/AHA is systolic/diastolic, 130/80 mm hg and for ESC/EHA is 140/90 mm Hg blood pressure. The International society guideline is similar to ESC/EHA recommendation (Unger). This change in definition epidemiologically would result in a change in prevalence from 31.9% to 45.6% in US population. (Munter) and treatment directed to achieve the new set ACC/AH goal would probably decrease 3 million less events in 10 years (Bress). This new definition would also decrease 1.5 -2 times higher adverse cardiovascular events in those classified with prehypertension by JNC-7 definition (Huang,Ettehad)

Knowledge discovery in database (KDD) on Blood Pressure Time Series through operative system.

The process of creating a platform for generating continuous data alone is insufficient unless a supporting tool for data curation and translation of incoming (PGBMD) is made possible. Technically now it is possible to translate raw time series numerical parameters into quantified finite scales as aggregates and detect phase transition pattern with improved precision. This can support clinical team in fine tuning of medication with confidence during clinical management of hypertension.

Similarly, access to repeated pulse measurement permits deeper analysis of components to complement systolic and diastolic blood pressure readings and expand knowledge and understanding on factors beyond systolic and diastolic BP.

Bridge customer and clinic demand.

The operation system designed to support customers with specific disease condition can assist clinical team with robust quality data on blood pressure and pulse. The adaptive technical platform with uniquely structured data translational behavior can perform technically complex analysis and process the data at the provider end and make it easily accessible, a valuable tool to clinical care givers. Furthermore, direct systematic iterative information interfacing can save clinical team time and assist providers to visualize integrated running report on trend, several new components on blood pressure and pulse in the electronic medical record.

Challenges in adopting guideline and strategy to be equitable operation.

The variation in blood sugar, pulse, temperature and blood pressure is a normal phenomenon. Thus, recommended goals need to address blood pressure and pulse dynamics (exacerbators, seasonal or other variation, compliance to treatment) and attempt to address share operational similarity adopted in diabetes. The practical burden that comes with the guide lines for hypertension detection and management though considers patient factor operationally, they are less realistic to generate data routinely and deliver patient centered care in the management of hypertension. The guideline for Ambulatory Blood Pressure Measurement (ABPM) gold standard for blood pressure assessment, is done at frequent intervals and, under less restrictive way than one recommended for clinic (CBP) or home blood pressure (HBP)monitoring. The practical aspect of operational prerequisite contained in the new statement; Measurement of Blood Pressure in Humans AHA statement, (Munter) is even more complex to adhere to as routine in a natural clinical setting.

The collection of data in research setting is a designed and is a standardized operation often, participants are screened. The complex process of analysis of data in research is outside the scope of every day clinical practice. Thus, the demand to collect quality of data for detection of change at this new-low blood pressure threshold range demands repeated true estimate in patient’s natural setting (Home Blood Pressure) for management and sustenance.

HBPM is economical and robust repeated HBP can aid in processing data to provide better Gaussian estimate and miscellaneous components on blood pressure. Detection of masked hypertension is currently limited to select few who exhibit high blood pressure using ambulatory blood pressure device outside the clinic. White-coat hypertension is yet another phenotype, high blood pressure here is conditional to office observation but true status out-of-office setting is left to assumption. Patients who display nocturnal high blood pressure and absence of nocturnal dip in blood pressure require appropriate device to capture these unique features.

Analysis of blood pressure and pulse components.

The clinical significance attached to components of blood pressure and pulse, variability, mean arterial blood pressure, pulse pressure etc…, requires facilitative regularized operation to be meaningful to clinical care giver in the management of hypertension. The knowledge on variability and other components of blood pressure and pulse is new hence, the process requires system level operation that is able to support data processing and usage friendly data display. The collection of data on patient's generated blood pressure and pulse data can be cost effective and assist access to abundant data for processing at regular intervals.

Blood pressure variability.

The guide line for standard of management of hypertension traditionally targets average systolic and diastolic blood pressure values. In clinical research additional factors such as blood pressure variability, pulse, pulse variability, pulse pressure, mean blood pressure and ankle brachial index and parameters on vascular mechanobiological dynamics are being used to identify individual's attendant clinic risk to project cardiovascular complication during one's life course. Some of these parameters are measured in every day clinical practice but, do not get processed for lack of resources to process the data. The potential for collecting data set similar to research is possible with evolving assistance from information technology (IT). The process, self-monitoring blood pressure and pulse, increase in access to robust repeated measurement and with IT support it is possible to analyze and assemble the data and generate additional physiological parameters (components) on blood pressure and pulse in clinical practice. (Bakris)

In recent years analysis of serial measurement of blood pressure by various methods have led to detection of other components and their added clinical value to risk prediction beyond mean blood pressure in individuals (Rothwell). The measured variation in blood pressure during clinic visit is one such component and accepted as not a random oscillation in blood pressure observation. Hence, significance to repeatedly observed variability is being recognized as possible additional cardiovascular risk. Besides, systolic and diastolic variability may have differential effect on risk, systolic being more related to cerebrovascular events and cardiac events being more apparent in those with diastolic blood pressure variability (Dai)

The clinical risk related to variability in blood pressure around accepted target mean value of blood pressure has gained increasing attention. There seems to be association of increased cardiovascular risk and extent of blood pressure variability (Stevens,Chia). Thus, there is need to consider minimizing variability in blood pressure both short- and long-term, with the potential to change cardiovascular morbidity and mortality in clinical practice. (Fratolla, Grove Rothwell, Gosmanova).

Blood pressure being a dynamic physiological parameter variation in BP is affected by heart beat to-beat, time varying time intervals. Furthermore, postural, circadian, seasonal variation are other factors associated with changes in blood pressure characteristic (parati). Variability in blood pressure is higher with advancing age, in woman (Hastie) and in patients with diabetes and kidney disease (Wan,Hata). The approach to management of hypertension therefore recognizes the value of control of mean blood pressure and introduces importance to detection of variability in blood pressure in routine clinical care.

Smoothness Index (SI)

Assessment of smoothness is another numerical measure of quality of blood pressure control. Determination of SI on variability trend may provide additional measure of quality of blood pressure control (Rizzoni)

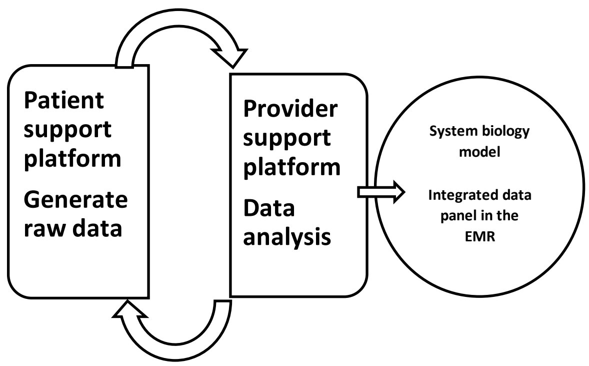
Profiling vascular characteristic.

The measurement of pulse pressure, difference between systolic and diastolic blood pressure (SBP – DBP) and a reflection of vascular characteristic, is not routine in practice. This assessment has received minimum attention in the most recent the American Heart Association Task Force on clinical practice guidelines in 2017(Whelton). In contrast European guideline considers pulse pressure as adjunct cardiovascular risk marker (Williams). The widening of pulse pressure is a recognized sign of arterial distensibility or loss of elastic recoil thereof, is a reflection of change in vascular function. These changes could precede consistent change in systolic blood pressure. Therefore, profiling pulse pressure change in clinical practice can support clinical provider with more information during patient interaction. Those who have white-coat hypertension, patients who do not qualify based on absolute systolic blood pressure readings can benefit from life habit change or more. (Scuteri).

However, there is no existing strategy in clinical practice to process clinic data and profile blood pressure aggregates or pulse for stratification to finite categories and sequential integration for tending and integration as panels in the EMR.

Home blood pressure by virtue of large numbers, provides a unique opportunity to assess better estimate of BP and variability. Blood pressure variability assessment have used various method measurements (Ambulatory blood pressure, Clinic blood pressure and home blood pressure). However, it remains unclear how best this can be adopted in every day clinical practice. Considering the number of variables likely to influence individual’s blood pressure, home blood pressure is easy to monitor and the robust number that can be accessed continuously lends to deeper insight to variability and momentary evets with some linearity. This process of data collection and processing can be simplified with operation system functionality behavior to perform serial analysis on validated home blood pressure data. Such and undertaking can simplify the demand on clinical care givers time with range of training. Similarly, additional factors on individuals repeated blood pressure such as; coefficient of variation, successive variability, mean arterial pressure and double product can be generated through operation system.

Blood pressure variability (short term, very-short, mid-term and long-term) Systolic and diastolic variability, Average real variability and successive variability, coefficient of variation, mean arterial blood pressure, double product are being recognized factors worth understanding in the management of hypertension. In the management of hypertension accessing abundant home blood pressure readings supports better assessment of estimates and finite data stratification. The objective here is to establish stakeholder's distinctive need and enable adaptive fit with distinct system behavior and capabilities to address preferred activities in disease management.



The application device address disease specific behavior with two distinct functions. The input component executes patient's activities. The platform supports to collect disease specific raw data from the patient and output platform on the clinical setting side assembles incoming data for screening, recognizes care givers objective for data analysis and formalization. These two are independent yet, retain intrinsic relationship to execute disease specific tasks.

Disease specific characterization of blood pressure and pulse.

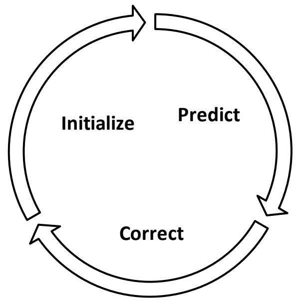
Blood pressure:	
1, Curation	Screening raw data
2, Estimates	Assembling data for weekly, monthly, quarterly and yearly aggregate report (time varying signal)
3, Characterization	Average Real variability (ARV)
	Coefficient of variation (CV)
	Successive variability
4, Form Factor Meaney	Mean arterial blood pressure. (MAP). measure of central tendency DBP + 0.412 x PP
5, Monthly PPav X SBPav	Blood pressure Double product (Measure of blood pressure load)

6, Pulse	Assembly of averages
	Pulse variability (weekly, monthly, quarterly, yearly)
	Pulse pressure (SBP-DBP)
7, Fractional PP Nakayama	PP:MAP
8, sHASI Govish	Symmetric Home blood pressure Arterial stiffness Index (sHASI= 1-1/PSR or sdSystolic/sdDiastolic)
9, SI	Monthly Peak to trough ratio on variability (Smoothness index)
10, ABI	Ankle Brachial Index. Peripheral artery disease index

Furthermore, this method has the potential to advance deductive information and its determinants on repeated blood pressure and pulse from natural setting. It is unclear if more knowledge on blood pressure variability and components of pulse improves patient care.

Kalman filter and its value monitoring blood pressure trend.

Kalman filter in its basic principle is a linear quadratic estimator of joint probability on unknown variable with more accuracy than single estimate alone. The process of optimizing blood pressure data trajectory assumes Gaussian distribution of post-prior and prior latent components in latent components there from express weighted estimate on current state. The algorithm is a recursive process of characterization of previous state and its uncertainty matrix, combine various averages to produce best estimate of current state



Deriving artery stiffening index from blood pressure components.

Stiffening of the arteries is a reflection of biological change in the arteries.

Principle behind this process assumes linear relationship within individual repeated systolic and diastolic blood pressure measurement. By integrating data scatter Systolic (X) versus Diastolic (y) and Diastolic (y) versus systolic (x) scale-independent symmetry therefrom one derives principle component line with the knowledge $\overline{x}$ intersects $\overline{y}$ offers single transitive equation on two independent linear variables.

$$PSR=\frac{sdSBP}{sdDBP} \text{ (ref Gavish)} \quad \& \quad sHASI=1-\left(\frac{1}{psr}\right)$$

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