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MOBILE & WIRELESS HEALTH

A Systematic Review of Wearable Systems for Cancer Detection: Current State and Challenges

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Abstract Rapid growth of sensor and computing platforms have introduced the wearable systems. In recent years, wearable systems have led to new applications across all medical fields. The aim of this review is to present current state-of-the-art approach in the field of wearable system based cancer detection and identify key challenges that resist it from clinical adoption. A total of 472 records were screened and 11 were finally included in this study. Two types of records were studied in this context that includes 45% research articles and 55% manufactured products. The review was performed per PRISMA guidelines where considerations was given to records that were published or reported between 2009 and 2017. The identified records included 4 cancer detecting wearable systems such as breast cancer (36.3%), skin cancer (36.3%), prostate cancer (18.1%), and multi-type cancer (9%). Most works involved sensor based smart systems comprising of microcontroller, Bluetooth module, and smart phone. Few demonstrated Ultra-Wide Band (i.e. UWB) antenna based wearable systems. Skin cancer detecting wearable systems were most comprehensible ones. The current works are gradually progressing with seamless integration of sensory units along with smart networking. However, they lack in cloud computing and long-range communication paradigms. Artificial intelligence and machine learning are key ports that need to be attached with current wearable systems. Further, clinical inertia, lack of awareness, and high cost are altogether pulling back the actual growth of such system. It is well comprehended that upon sincere orientation of all identified challenges, wearable systems would emerge as vital alternative to futuristic cancer detection.

Keywords Wearable monitoring systems · Wearable devices · Cancer detection · Internet of things

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Introduction

Recently, there has been an overwhelming explosion of demand for smart e-health care around the globe. Several chronic and acute diseases, including general health status, are currently being monitored, detected, and managed by means of integrated e-health systems (comprising software and hardware) [1]. Although, acute conditions (such as gastroenteritis, cold fever, flu, neck injury etc.) are normally curable with help of pathological tests, drugs, and proper medications, chronic ones (that includes heart disease, cancer, diabetes stroke, arthritis etc.) are not [2]. Major contributing factors are irregular life style, unhealthy food habit, heredity, and economic downturn [2]. Per a recently published report from the American Cancer Society, around 1,688,780 new cancer patients will be diagnosed and 600,920 cancer patients will die in United States in 2017 [3]. Apart from ruthless deaths in cancer patients, huge monetary expenditure cannot be ignored. in United States alone, annual expenditure in health care is in the range of $US 210.9 billion to $US 306 billion [4]. The study somewhat like the United Kingdom where 29% population is currently under-going some sorts of chronic diseases that incur 80% of health budget into management of such diseases [5]. At this point, we can argue that despite of availability of standard health care facilities (super specialty hospital, specialized trauma care service, qualified medical professionals, and diagnosis system etc.) more intervention is indeed required that could leverage more flexible, hassle free, and user-friendly services to cancer patients. Hence, a new alternative is envisaged.

As of now, web based telemedicine, smart phone based APPs, and smart wrist bands are being used as key to pervasive e-health care in all domain of diseases [6]. The problems behind these approaches are lack of adaptability, heterogeneity, reliability, cost, and user-friendliness [6]. Suppose for example, a health tracking wrist band measures pulse rate and notifies the user, a smart phone APP notifies menstruation cycle of a woman and a telemedicine web site provides a dialogue between a patient and medical professional. In respective cases, if wrist band gets lost or damaged or user forgets to enter first menstruation date in APP, or web site is crashed, the patient is at complete loss and debarred from appropriate health services. Besides, each of these technologies are based on different layers of protocol stacks which resists one to interact and cooperate with other. For example, a Bluetooth enabled smart wrist band may not be capable to transceive (i.e. transmit and receive) data to and from the web based telemedicine site or smart phone based APP may not get updated with web based telemedicine service. Hence, it would be great if such vertical silo (i.e. one rule for each system) could be demolished and a unified genre of systematic approach be placed.

Wearable systems (i.e. WeS) are emerging as an alternative tool to tackle early diagnosis, prevention, and management of chronic diseases. WeS may be defined as a composition of electronic elements that could be worn on human body as an accessory or part of material used in clothing. Often, these wearable systems are equipped with smart bio-sensors, actuators, in-built Direct Current (i.e. DC) power sources, communication modules, and processing units. The worth of WeS is estimated to reach $US 51.60 billion within 2022 [7]. In this context, we cannot surpass the Internet of Things (i.e. IoT) which has tremendously imparted on this growth of WeS. The reason is as follows. IoT is aimed at correlating heterogenous communication protocols (e.g. communication, hardware) and objects (i.e. things, sensors, actuators) with existing Information and Communication Technology (i.e. ICT) infrastructure (i.e. cloud, edge services) [8, 9]. WeS, being a resource constrained system, has very limited capability to sense, compute, actuate, and decide. Hence, incorporation of IoT would certainly assist WeS to propagate its objectives toward more precise and meaningful way, resulting into a better e-health care. Another vital reason is low manufacturing cost of existing bio-sensors, actuators, and body-worn e-textiles which has undoubtedly helped WeS to get wide spread and popular [10].

Several research initiatives are already taken to develop disease specific WeS that includes (1) the VitalPatch is an WeS that reminds user to take deep breath [11], besides it measures heart rate, sleep pattern, body temperature, and step count during walk, the measured data is paired with external Bluetooth-enabled WiFi gateway to send and store in a remot cloud for further analysis; (2) an experimental design is proposed to measure human Body Core Temperature (i.e. BCT) at a distance by using a MLX90614 Infra-red senor, to be worn with help of a hat [12]; (3) a wrist-wearable pulse sensing system is developed that employs MPXM2053D piezo-resistive pressure sensor to measure pulse rate from wrist; (4) design of RunScribe to assist athletes get informed about kinematics of their feet while running, it uses 9-axis sensor comprising of a gyroscope, a accelerometer, and a magnetic compass [13, 14]; (5) development of the SmartVest, a WeS which is comprised of a vest and a few physiological monitoring-sensors, all integrated into the user's garment's fabric to sense and collect different body-signals [15]; (6–8) three projects from the European Information Society Technologies Sixth Framework Programs (i.e. IST FP6) (such as HeartCycle, MyHeart, and MERMOTH) which present timely examples of WeS solutions [16–19].

Despite of promising design and multiple trials, WeS-based health care facilities are mainly restricted to acute diseases and collection of vitals from body. Early detection of Cancer, diagnosis, and management are severely ignored, except a handful of research.

The aim of this systematic review is (1) to investigate how WeS research is currently catering the needs of cancer affected people; (2) to reveal how different WeS products (manufactured by research groups and companies) are being used to detect and manage different cancers; (3) to highlight challenges associated with adoption of WeS among cancer patients, and (4) to provide recommendation so that community centric adoption of WeS into cancer is achieved in near future. Table 1 presents key abbreviation and full terms.

The paper is organized as follows. Section II presents detailed methodology employed to conduct this review. Search results obtained from this study is also presented in this section. Section III presents discussions on several key challenges behind adoption of WeS into cancer care. Section IV concludes this article.

Materials and method

We followed PRISMA guideline [20] to mine through available records over six digital libraries that includes Nature, IEEE Xplore Digital Library, Science Direct, Pubmed, Pubmed Central, and Springer Link. We search these libraries using following key words such as "Wearable Cancer" or

Table 1 Abbreviation and key terms

Abbreviation	Full forms
BCT	Body Core Temperature
BLE	Bluetooth Low Energy
CBR	Circardian Biometric Recorder
CISC	Complex Instruction Set Computer
dB	Decibel
DC	Direct Current
DIP	Dual In-line Package
DSP	Digital Signal Processing
ICT	Information and Communication Technology
IDE	Integrated Development Environment
IoT	Internet of Things
IR	Infra-Red
LED	Light Emitting Diode
MRI	Magnetic Resonance Imaging
mRNA	micro-Ribonucleic Acid
OLED	Organic Light Emitting Diode
PDT	Photo-Diode Therapy
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RISC	Reduced Instruction Set Computer
SNR	Signal to Noise Ratio
SOIC	Small Outline Integrated Circuit
UV	Ultra Violet
UWB	Ultra-Wide Band
VHDL	Very High Speed Integrated Circuit Hardware Description Language
VLIW	Very Long Instruction Word
WeS	Wearable Systems

"Wearable" or "Wearable Cancer Detection" or "Wearable Detection" or "Cancer Detection" and "Wearable Health". Additionally, we searched www.wearable-technologies.com and www.postscapes.com to include manufactured WeS products in this review. Our search was last conducted on July 21, 2017.

A) *Articles selection and exclusion criteria:* One of the authors performed initial screening while eliminating duplicate records from preliminary search. Later, additional records were removed per unsuitability of individual title of article and abstract. A second author, then reviewed included studies (including articles and product information) and went through full-article evaluation to find eligible records for final review process. The eligibility criteria were based on following points:

- Original articles published in a peer-reviewed journal article or appeared in a conference proceeding
- Article publication or reporting year (inclusive) 2009 to 2017
- Wearable systems (an embedded system comprising hardware and software) for cancer detection was the main aspect of this review
- Targeted towards cancer detection products were also included
- Articles written and published in English

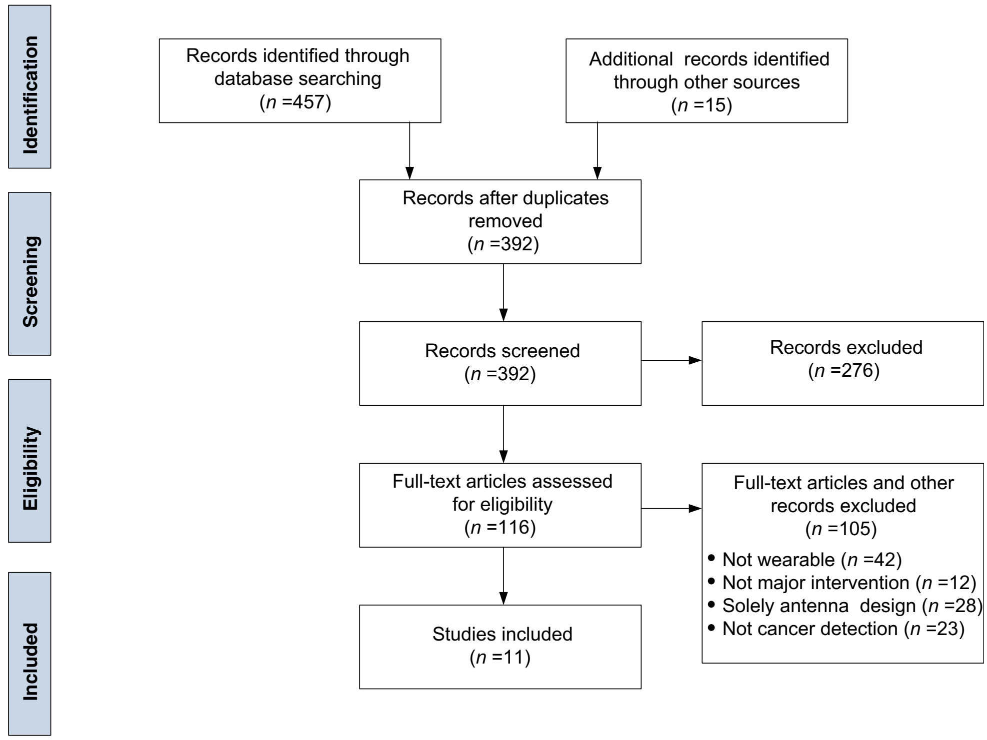
As this work mainly focuses on detection of cancer through WeS, review and survey articles were excluded. Smart phone based findings were excluded since smart phones are usually not worn over body. Several publications on simulation and design of UWB antenna were sought, but WeS (i.e. software and hardware integration) aspect as missing, hence excluded.

B) *Article search results:* Initially, 472 records (457 articles +15 WeS product information) were identified through digital library searching. After removing duplicated records, 392 records were found suitable for screening. 276 records did not match our inclusion criteria at initial screening. A total 116 records were sought for full text reading and analysis. These full texts were reviewed by two other authors. After excluding 105 records, 11 studies (articles and products) were finally selected for final review. Fig. 1. presents the study selection process per PRISMA compliant. Category wise WeS based cancer detection is shown in Fig. 2. Brief description of all 11 studies are illustrated in Table 2 (article wise cancer detection) and Table 3 (product wise cancer detection). A brief compaction of grouped parameters of WeS based cancer detection in reviewed studies is provided in Table 4. Figures 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 present physical structure of developed and research models.

Discussion on challenges to clinical adoption

The upcoming generation of WeS is likely to progress the worth of human life by assuring high relief from tiredness of regular diagnosis process of cancer detection while utilizing resource constrained facilities. Further improvements in e-textile based wearable sensor design, short-range bio-signal quality, product miniaturization, and efficient data gathering techniques are indeed required to cope up with these expectations. Following discussions intricate the challenges considering to these four vital domains. Fig. 14 presents overall architecture of WeS based cancer detection system.

Fig. 1 The study selection process



A) *Sensor System and Informatics:* Included studies are highly dependent on different sorts of flexible substrates to contain developed sensor systems onto it. In some cases, Kapton is used as substrate of proposed systems [22]. Kapton is a polyimide film earlier developed by the Dupont to cater high temperature susceptibility. In most cases flexible substrates are used to provide place to hold the sensor based electronic circuitry [23, 26, 28, 29]. Sometimes, flexible substrate is solely made from copper layer on non-conductive ordinary polyimide layer. The problem behind such approach is multi-fold such as (1) high fragility, (2) high bendability, and (3) non-cooperative form factor. Despite of limitations of flexible substrates, Kapton proves to be best suitable in this scenario [32]. Carbon nanotube does inherit high strength, low weight phenomena, thus making it an alternative to this problem. Graphite and charcoal could also act as key imprinting element to design circuits over flexible substrates in effective way. However, "carbon based imprinting solution" provide high sheet resistance (Ohm-cm^2). But, its inherent attributes surpass this issue. Furthermore, e-textile elements are continuously getting popular [29]. Such fabrics are efficient enough to hold electronic paths (i.e. wires) to be woven with help of conductive thread. Microcontroller is another component that helps a

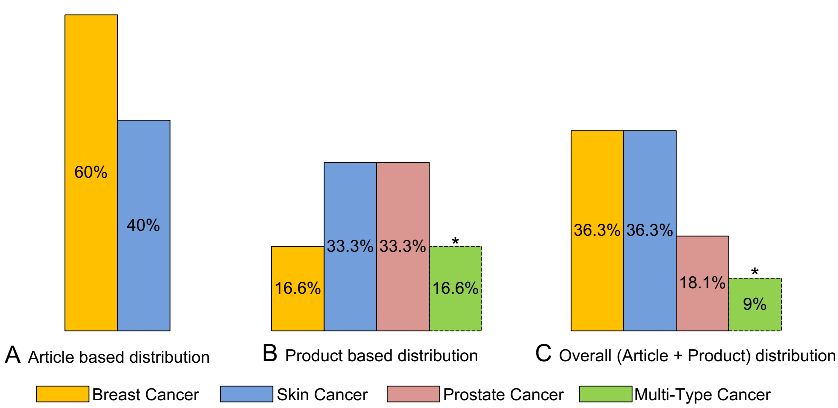


Fig. 2 Overall distribution of WeS based cancer detection. **a.** Articles ($n = 5$) where WeS based Breast cancer detection ($n = 3$) and Skin cancer detection ($n = 2$). **b**. Products ($n = 6$) where WeS based Breast cancer detection ($n = 1$), Skin cancer detection ($n = 2$), Prostate cancer detection ($n = 2$), Multiple cancer detection ($n = 1$). **c**. Overall distribution ($n = 11$) where WeS based Breast cancer detection ($n = 4$), Skin cancer detection ($n = 4$), Prostate cancer detection ($n = 2$), Multi-type cancer detection ($n = 1$). *Multi-type cancer detection is included in calculation although it is a conceptual-wearable device that may be used for multiple type of cancer detection

Table 2 Brief description of 5 studies included as article

Author, Year, and Country	Type of cancer detected	Types of sensors/ Platforms used	Objectives (OB) and Outcomes of Study (OC)
S. K. Attili et al. 2009, UK [21]	Skin Cancer	Aktilite® inorganic Light Emitting Diode (i.e. LED) source, organic light-emitting diode (i.e. OLED) 2 cm diameter, Ansmann 2600 mAh AA batteries	OB: To present a low-irradiance, potentially disposable, lightweight, organic light-emitting diode based Photo-Dynamic Therapy (i.e. PDT) for skin cancer detection OC: An OLED based device was developed and 7 of the 12 participating patients who were treated at the1-year follow-up, gave positive response
H. Bahrami et al. 2015, Canada [22]	Breast Cancer	50 μm Kapton polyimide with relative permittivity 3.5, miniaturized and flexible monopole and spiral shaped single and dual polarization antenna of 20 mm × 20 mm antennas, with 240 signal per scan, measured at 160 GSa/s with 4096 samples/signal	OB: To design a light weight, low cost, flexible and microwave array of antenna to detect breast cancer OC: 16 UWB) flexible antennas on same Kapton substrate are developed to place over breasts keeping nipple at the center of the structure. Use of reflectors have increased penetration of electro-magnetic wave into breast tissue in the range of 2.6–3.3. Further, the antenna array is capable to work around 2–4 GHz
A. Rahman et al. 2016, Malaysia [23]	Breast Cancer	Organic flexible substrate having 1.6 mm thickness, a rectangular patch having 14 × 18 mm^2 dimension, 4-(perfluorohexyl) bromobenzene with corresponding 5-formyl-2-thiophene broronic acid based synthetic compound, and Agilent N5227A PNA network analyzer	OB: To design a compact and UWB antenna on a flexible substrate using microwave imaging for breast cancer measurement OC: A bi-static radar based imaging system that consists of two omnidirectional antennas operates at 4–6 GHz that attains >70% efficiency and having 1 dB (i.e. dB) average gain during bending in and around breast
F. Teng et al. 2017, USA [24]	Breast Cancer	LED pairs (SMT750–23 and SMT850–23, Roithner Lasertechnik) with peak emission wavelength of 750 and 850 nm, two mil (51 μm) copper and polyimide, optical detector (TSL250RD, ams AG), LDX-3525B, 74HC/HCT4514, ILX Lightwave	OB: To develop a diffusion based optical probe that works on theory of continuous-wave to provide hemodynamic response during neoadjuvant chemotherapy infusions. OC: The resultant system is comprised of a flexible printed circuit board that supports an array of 6 dual wavelength surface-mount LED and photodiode pairs. Evaluation of probe based performance was tissue-simulated on phantoms through in vivo measurements. High Signal to Noise ratio (i.e. SNR) of 71 dB, low source-detector crosstalk (i.e. −60 dB), high measurement precision (i.e. 0.17%), and good thermal stability (i.e. 0.22% Vrms °C) were achieved.
D. D. Godoy et al. 2017, USA [25]	Skin Cancer	Nordic nRF51 Bluetooth Low Energy (i.e. BLE), temperature sensor, a humidity sensor, a light sensor, and a UV sensor	OB: To develop a low-cost, wearable, IoT based Ultra Violet (i.e. UV) index measurement for skin cancer detection OC: A hat-wearable smart sensor system is developed that measures temperature, humidity, light, and UV from ambient environment and notifies user through BLE about possible UV-harm by smart phone based APP.

Table 3 Brief description of 6 studies included as device

Device, Developer, and Country	Type of Cancer detected	Types of Sensors/ Platforms Used (SP) and What it detects (WD)	Smart Phone incorporated	Target organ to wear	Type of wearable
My UV Patch, La Roche-Posey, USA [26]	Skin Cancer	SP: UV photo-dyes, Ultra-thin flexible layer of UV receptive layer, Image based analysis WD: UV index on skin from the SUN	Yes	Hand	Adhesive Patch
Violet® Plus, Ultra Inc., USA [27]	Skin Cancer	SP: UV sensor, Battery, Microprocessor, Bluetooth, Analog-to-Digital convertor WD: UV radiation on skin from the Sun	Yes	Hand, Waist	Clip Attached Module
ScanMed Prostet/Pelvic Coil, USA [28]	Prostate Cancer	SP: Light-weight SemiFlex™, flexibleliquid impermeable,biocompatible materials, phased array magnetic resonance imaging (i.e. MRI) coil WD: MRI image from pelvic region	–	Wait	Waist Diaper
VylyV Smart Shorts [29]	Prostate Cancer	SP: e-Textile, Bluetooth, Flexible pressure sensor, CR battery, Wireless charger circuit WD: Pelvic floor muscle stress and kegel exercise	Yes	Waist	Waist Shorts
iTBra, Cyrcadia Health and Nanyang Technological University, Singapore and USA [30]	Breast Cancer	SP: Cyrcadia Health Circadian Biometric RecorderTM (i.e. CBR) system, Machine learning based predictive analytics software, Thermistors embedded flexible garments WD: Circadian temperature changes within breast tissue	Yes	Breast	Breast patch
Optical Cancer Detector, Memorial Sloan Kettering Cancer Center, USA [31]	Multi-Type Cancer	SP: Needle-like carbon nanotubes placed at key sites into skin of body, Infra-red light emitter, Infra-red light detector WD: microRNA biomarkers circulating in blood	Yes	Wrist (Hand)	Watch-band

Table 4 Grouped parameters of WeS based cancer detection in reviewed studies

Parameters	n (%)
Implementation type (n = 11)	
Antenna based	4 (36)
LED based	3 (27)
Sensor based	4 (36)
Form Factor (n = 11)	
Patch type	3 (27)
Band type	2 (18)
Vest type	3 (27)
Shorts type	1 (9)
Hat type	1 (9)
Diaper type	1 (9)
Smart Phone Incorporation (n = 11)	
Products	5 (45)
Research articles	1 (9)
Flexible Substrate Incorporation (n = 11)	
Products	3 (27)
Research articles	2 (18)
e-Textile based (n = 11)	
Products	1 (9)
Research articles	1 (9)
Bluetooth based Communication (n = 11)	
Products	5 (9)
Research articles	1 (9)

sensor systems to complete in terms of computability and decision making purpose [24, 25, 27, 29].

Now-a-days, various forms (e.g. Small Outline Integrated Circuit i.e. SOIC, Dual In-line Package i.e. DIP etc.) and families (Reduced Instruction Set Computer i.e. RISC, Complex Instruction Set Computer i.e. CISC, Very Large Instruction Word i.e. VLIW, Digital Signal Processing i.e. DSP etc.) of microcontrollers are available in market. The bus width (e.g. 8, 16, 32, 64 etc.) and clock speed (600 MHz, 800 MHz, 1.2GHz, 1.5GHZ etc.) are also different from one microcontroller to other. This surely creates a confusion for developer to choose a particular type of microcontroller. Probable solution of this issue could be application specific. For example, if application requires image based breast cancer detection [22, 23, 28] then it is good to go for high bus width and high clock speed based microcontroller. Otherwise, if it is just to check UV index or pelvic muscle temperature [21, 24, 25, 27, 29, 31], then low bus width and less clock speed based microcontroller could be justifiable. System (i.e. product) miniaturization is another challenge that should be considered with utmost care. All the surveyed studies

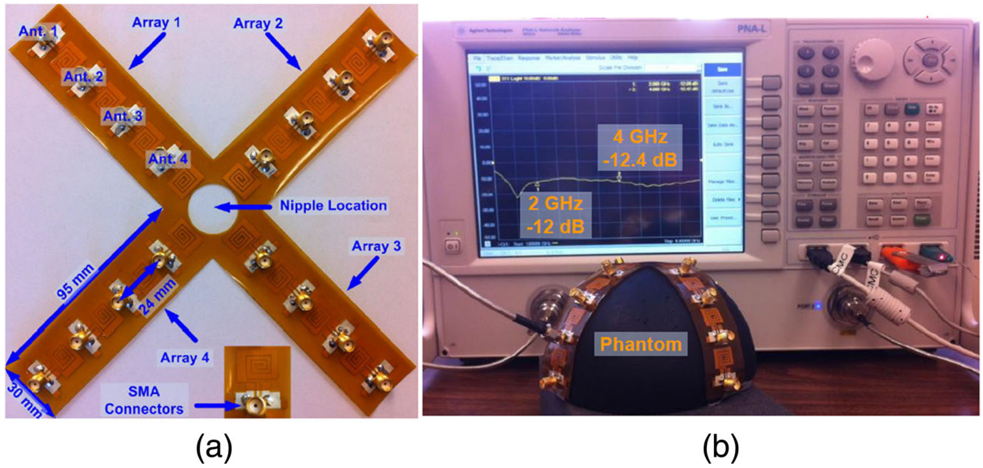


Fig. 3 **a** Top view of the SMA antenna array, (**b**) S-parameter measurement set up [22]

present low form-factor-wise design to help cancer patient wear on his/her body. But, the microcontroller chips, signal processing chips, analog-to-digital converter chips need to more flexible and minimum sized so that the developed systems could be miniaturized to optimize level. Subsequently, another challenge originates from such consideration i.e. complexity to fabricate the whole design. Advanced VHSIC Hardware Description Language (i.e. VHDL)/Verilog based IDE/simulation tools are indeed needed to cater this problem.

Machine learning and artificial intelligence techniques are now being widely used in all fields of science and technology. Medical science is not far from its reach [33]. This provides an effective opportunity to get

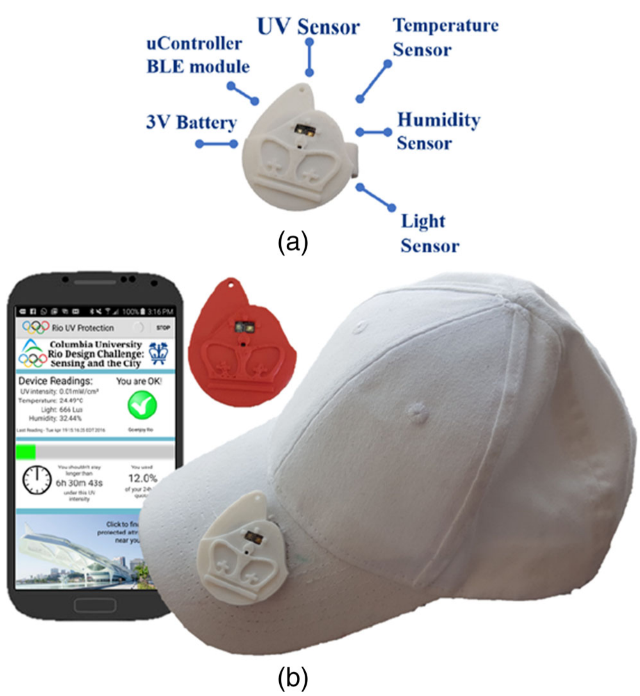


Fig. 4 **a** RIO-40C tag break down, (**b**) RIO-40C app and tag, and hat with tag [25]

involved with WeS to perform analytics as and when needed at local machine.

B) *Connectivity:* Another challenging aspect of surveyed studies is connectivity. Undoubtedly, inappropriate connectivity will reduce to credibility of the proposed systems to cancer patients. Connectivity, in this context, could be comprised of several notions such as (1) communication protocols, (2) integrity with host machine, and (3) cloud computing services. As the WeS is mainly focused on in-body attachments, short or very short-range communication protocols could be beneficial that includes Bluetooth, Bluetooth Low Energy (i.e. BLE), WiFi, Infra-red (i.e. IR), or visible light communication etc. this communication is required to assist detected body signals to send to local machines. For example, Violet® Plus [27] is worn on patient's wrist and he/she is currently in motion (e.g. walking, running etc.) and it periodically sends alerts to patients' smart phone that is kept inside shirt-pocket and the whole system is wireless. What type of communication protocol to be used? The answer is quite straight forward i.e. short range such Bluetooth or WiFi. Main task stars then. When, body-signal is received at the smart phone, it might sometimes be necessary to store or analyze the received signal in a remote cloud. The very facility is appropriate when no such service is available from local machine. ScanMed uses such convention [28]. In this context, the signal is to be forwarded to remote cloud for further analysis. Now which communication protocol is to be selected? This time it should be long range such as LoRa, 3G, 4G–LTE, 4G–VoLTE etc.

From this discussion, it is comprehended that an integration between local sensor-system and remote cloud is required. But, stage-wise approach (i.e. for

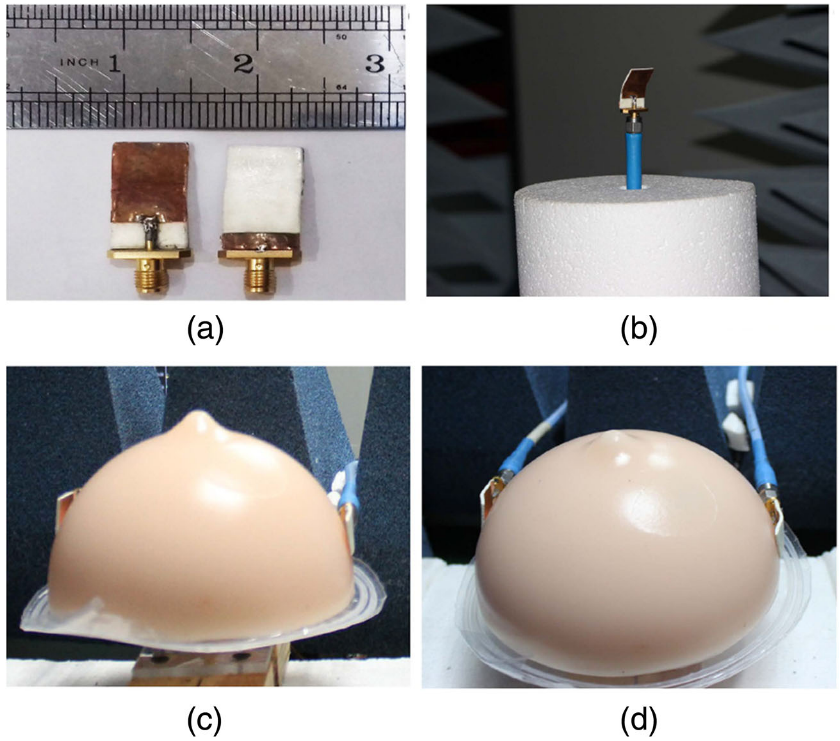


Fig. 5 **a** Prototype of flexible antenna, (**b**) Electromagnetic-performances at bending conditions, (**c**) Experiment setup with the antenna attached with the phantom skin, (**d**) Antenna attached at bending conditions [23]

sending information to remote cloud first use short range and then long range and to receive cloud services from remote facility first use long range, then use short range communication) in this

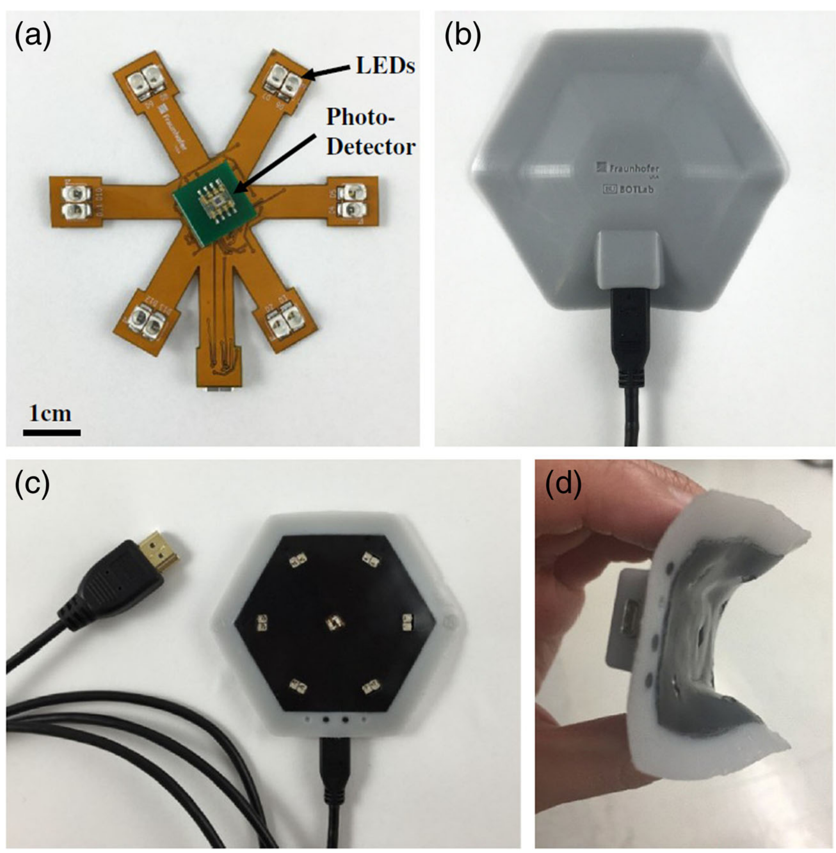


Fig. 6 **a** Flexible PCB and optical components (**b**) Top and (**c**) bottom view of the wearable probe, (**d**) Flexibility of the probe under gentle pressure [24]

Fig. 7 **a** Smart Phone APP (**b**) My UV Patch [26]

scenario cloud be difficult to manage. The case could be worse if multiple WeS enabled patients might require simultaneous services. This problem need to be solved by possible incorporation of IoT along with WeS. It is also worth to note that upon implication of IoT along with WeS, novel IoT gateway is to be developed that would manage heterogeneous protocols at one go.

As already discussed, IoT provides heterogeneous services among multiple devices, objects, platform and communication protocols, it should be wiser to implement IoT along with surveyed WeS to assist cancer patients in more flexible way. Currently, only one such WeS uses IoT to inculcate enlarged patient care.

In such context, one thing becomes a prevalent issue

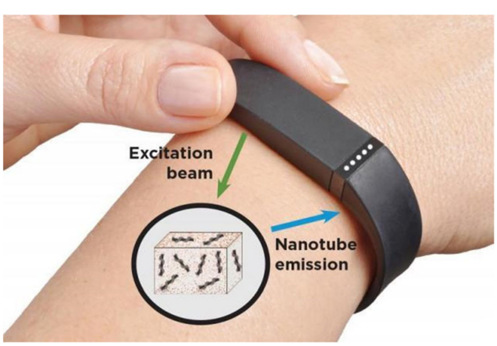


Fig. 8 Wrist-band of multi-type cancer detection [31]

Fig. 9 ScanMed bag [28]

i.e. antenna. Ordinarily, Bluetooth, WiFi, LoRa etc. modules come along with in-built antenna to transceive radiation (i.e. bio-signal). But, as in case of [22, 23, 28, 30], the antenna were developed at laboratory. That means similar apprehensions are going to increase in near future. In all the cases,

UWB (i.e. a radio-communication technology. It uses a very minimum energy for very short/short-range and moderate/high-bandwidth of more than 500 MHz communications. It also uses a very large portion of radio spectrum to manage such tasks.) antennas were used to propagate bio-signal from and to body and host machine. Although single pole and i-pole antennas were successfully used to detect cancer-wise bio-signal, hybrid and omni-directional antenna need to be investigated for further enhancement of the transceive activity.

C) *Clinical Inertia:* In practice, it has been observed that general clinicians including doctors, nurses, pathologists, radiologists, physiotherapists etc., are very

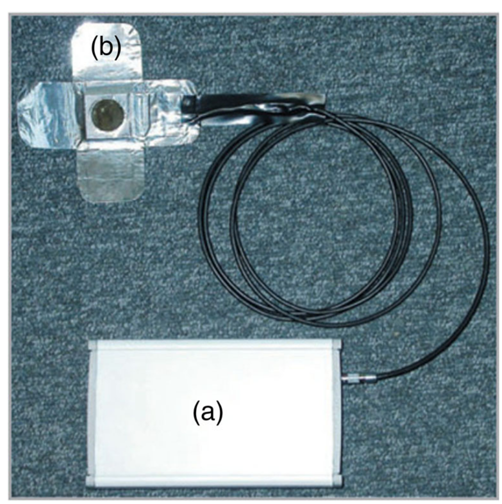


Fig. 10 **a** Power supply unit of 2600 mAh AA batteries, (**b**) OLED element [21]

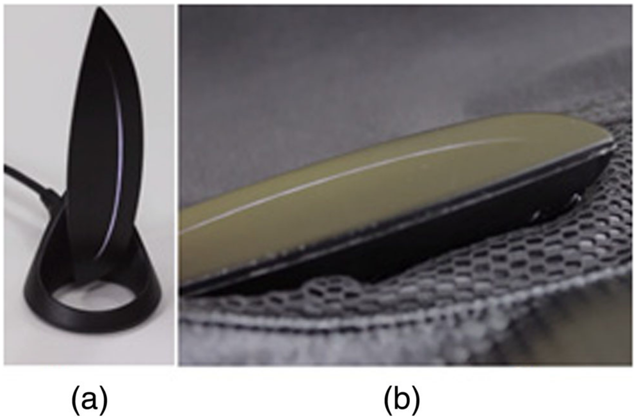


Fig. 11 **a** VylyV Smart device, (**b**) VylyV Smart Shorts [29]

less affectionate toward use of smart hand-held or body-attachable systems under their vicinity. Especially, WeS are very less prone to be utilized by current medical practitioners. The reason may be categorized into three domains such as (1) habit, (2) style of practice, and (3) low adaptability to hi-tech mentality. Unless otherwise stated, it would be great to assume that existing mind sets of such practitioners are yet to be developed toward adoption of novel usage patterns into medical science. It is well understood that governments receive huge amount of emoluments in form of various taxes from private health agencies, and drug manufacturers. Inclusion of WeS in main preform of medical practice shall obviously lower down other alternatives. Hence, the governance related inertia is sometime perceived.

Cancer, being a killer disease, needs proper and advanced strategy to cater with. For example, skin cancer patients should first be diagnosed with help of smart phone APP based image processing tools to identify preliminary signs of cancer. Upon,

Fig. 12 Violet® Plus [27]

Fig. 13 iTBra inside design [30]

continuous interactions of skin and sun rays, chance of skin cancer increases. Especially, white-skin.

people should always be given body-attachable UV ray detector as of [4, 21, 26, 27] when they are outing. Doctors should advice female cancer patients to go for wearing of bra-based WeS at least once they.

meet the doctor for such checkup. Obviously, some initial ethical adjustments between female breast cancer patient and doctor should be made prior to start the diagnosis procedure. Governments and health care agencies include private hospital chains and insurance partners should leverage a framework based on which a policy could be adopted to help-out WeS based cancer detection in clinics as well as patient's home. Hence, a standardization approach is expected to cope-up with negligence to diagnose, manage, and cure cancer in coming days.

D) *Awareness and Cost:* The last but not least is awareness. It is most vital pillar on which the WeS based cancer detection process and gain depends. Primarily, it is the job of Universities and higher institutions to incorporate appropriate syllabus into all existing bachelor and masters' courses of medical, nursing, physiotherapy, and radiology so that today's medical students get enough opportunity and time to learn, assimilate, and build self-confidence along with his/her mind set. In situations, where such degree courses are not available, 6–12 months training and certification would do the job. Governments should aware its citizens to be self-motivated to ask the medical practitioner for such WeS based inclusions into the check-up process. Advertisements in form documents, images, videos and cartoons could be spread throughout the country. Rural areas are especially important to touch where most of the population of the world reside. Under developed and developing countries should be the initial target of this activities. Children are future of our society. Hence, a small portion of study materials

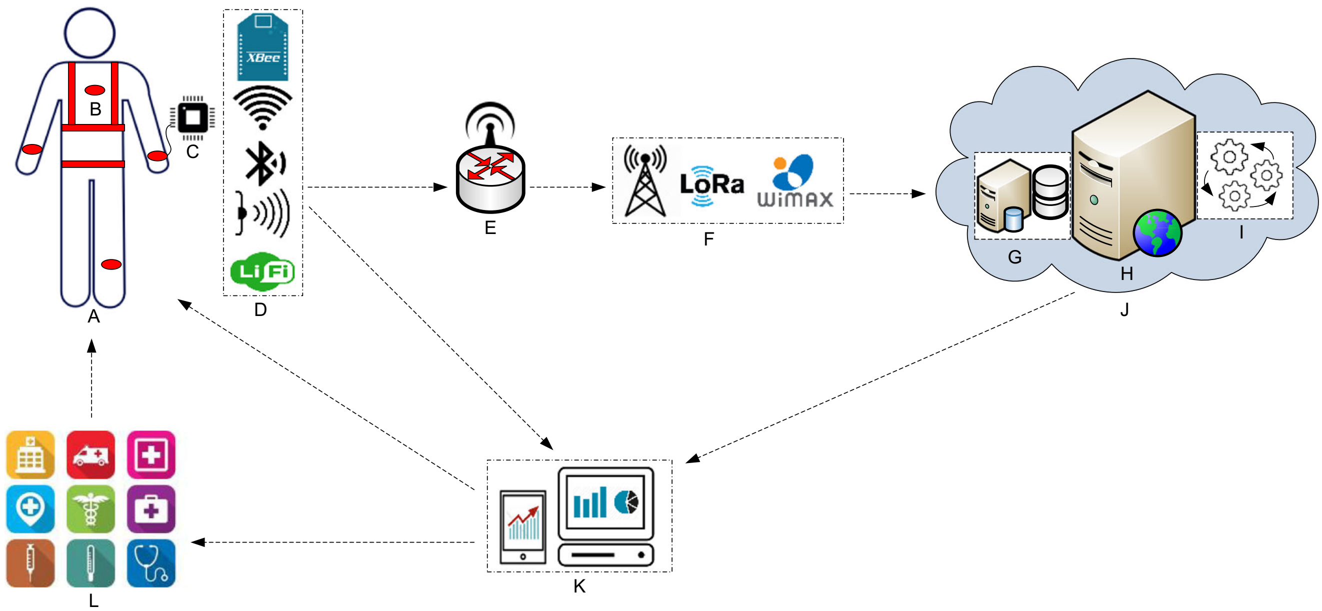


Fig. 14 Overview model of WeS. **a** Cancer patient and attached wearable sensors system as patch, band, vest, and belt; **b** Sensor deposition on body or skin; **c** Microcontroller and allied peripherals; **d** Low-range communication technology; **e** Smart gateway (i.e. IoT gateway); **f** Long-range communication technology; **g** Electronic health record (i.e. EHR) depository and cloud database server; **h** Cloud server; **i** Decision making and informatics services including artificial intelligence and machine learning; **j** Remote cloud platform; **k** Local visualization tools including PC, Smart phone etc.; **l** Hospital, care giver, and emergency service and medications

could be included into the school education to make them aware about what WeS is and how it is going to be used to tackle cancer diseases. Surely, cost is the resistor on this way. Developing companies and governments should come together to reduce the production cost and other sales taxes so as to make the people of all class afford such solutions.

Conclusion

Current publications and records exploring of Wearable Systems based cancer detection suggest that further in-depth cultivation into this technology is warranted. Selection of only 11 studies embark on the fact that more research and trials are indeed apprehended. It is also worth to note that 5 articles were selected from research publications where 3 were solely based of breast cancer detection. Out of 6 products 4 were prostate and skin related. Recent trend shows that demand of breast and skin cancer detection urge the most.

Despite of such small interventions toward WeS based cancer detection, we may be hopeful that upon serious inculcation of identified issues such inter-disciplinary e-healthcare growth shall surely increase in due course of time. Besides, IoT might play a crucial role to augment and propagate cyber-bio signals to and from cloud assisted facilities, which obviously is the demand of time.

We suggest that research incorporations should involve researchers and young mind into such novel genre of cancer detection process. Governments are nevertheless behind to act in this scenario. Proper cancer-health and cost reduction policy are seamlessly indebted towards its citizens. Finally, awareness campaigning is must to educate the minds of patients and medical practitioners to push them into such environment. We are hopeful that within next decade WeS shall be emerged as a vital alternative into cancer detection and management activities.

Compliance with Ethical Standards

Conflict of Interest Authors declare no conflict of interest.

Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

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