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AI-ML Integrated WSN Devices in Capnography and Hypoxia: Role in Preventive Cardiology During Medical and Surgical Interventions

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Abstract: Applications of AI and ML are expanding, exponentially in critical medical diagnosis. Deep learning has proven its prominence in population health. It has a distinct role in disease risk prediction. Both AI and ML are enhancing recognition of out-of-hospital cardiac arrests. Wireless Sensor Networks (WSNs) and IOT (Internet of things) are being increasingly integrated in health vitals monitoring in critical medical emergencies. Use of wireless sensor networks (WSN) with computational capabilities to monitor carbon dioxide levels (capnography) and hypoxia during per-operative general anesthesia while using an anesthesia machine in delivering mixture of anesthesia gases in critical surgeries can prevent medical emergencies. Wireless Medical Sensors are brought in intimate contact with body to collect critical physiological data. Modern Continuous anesthesia delivery machine administers a mixture of anesthetic gases. Real time monitoring of developing hypoxia with EEG, febrile condition, Blood pressure, rate of heart beat, convoluted carbon dioxide as an indicator of depth of anesthesia can be of immense use to help anesthesiologists plan a safer anesthesia. In case of a cardiac arrest, CO_2 produced at the level of tissues fails to get transported to lungs. Here is where the elimination of CO_2 takes occurs. In cardiopulmonary resuscitation estimation of that is produced in exhalation can be a guide in circulation assessment. In comparison to an electrocardiogram, blood pressure or pulse it serves better in diagnosis. It is generally Normoxia in a cardiac surgery decreases kidney injury. A sensors that is an attachment in a patient's body to gather patient's physiological data followed by concurrent wireless transmission of such data can be on circulated onto a Physicians portable device. In this publication, we make an attempt to achieve more insights into recent developments in Critical Medicine in particular applications focused on` how WSN and IOT can help maintain balanced Anesthesia with minimum cardiac arrest risk using a real time per-operative monitoring technique targeted towards hypoxia and end tidal carbon dioxide levels in blood.

Keywords: *Capnography, Artificial Intelligence, Anesthesia, Cardiac Arrest, Internet of Things.*

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I. INTRODUCTORY PERSPECTIVE

Acute Cardiac failure or arrhythmia during surgery can result from hypoxia, decrease in blood volume due to blood loss in surgery a drug interaction and vagal response to surgical stimulation medication or an interventional procedure. In managing cardiac arrest include adequate cardiopulmonary resuscitation (CPR), epinephrine, and defibrillation is essential. Monitoring oxygen and carbon dioxide levels in patients is crucial in preventing cardiac arrest during surgery. It helps identify and takes care of hypo ventilation, intubation, and any airway circuit disconnections in anesthesia where a default can lead to serious complications. Machine learning (ML) and deep learning (DL) have minimized Cardio Vascular Disease (Disease of Heart and Blood Circulation) risks. Algorithms to identify complex patterns in datasets can focus on discerning concealed correlations in clinical data. Though challenged by model interception and over fitting, ML and DL are in modern medicine revolutionizing CVD risk evaluation and management. In surgery, a waveform called capnogram helps anesthesiologists administers hyper-oxygenation during surgery. This avoids hypoxia. But, hyper-oxygenation can increase the generation of reactive oxygen. This can cause postoperative kidney and brain injury. AI and machine learning (ML) depict promising outlook in predicting and managing cardiac arrest with hypoxia in surgeries with early intervention and improved outcomes. AI algorithms analyze patient data to predict an impending cardiac arrest. Application of standardized monitoring equipment together

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with monitor data interpretation can alert the surgeon on unfolding events. Such events that can lead to cardiac arrest, this can direct proper resuscitation efforts in such an event. Today we have a aging global population. This is coupled with increase in respiratory infections. Also, organic respiratory disorders have increased. A vacuum for developing monitoring systems for capnography and hypoxia even with mechanical ventilation therefore is in existence. It is worth mentioning that in a recent times multiple episodes of **pandemic resulting from mutated and novel strains of SARS-CoV-2 and its variants has truly incited world's health systems and programs [1] Thus shortage of sensor devices which compose intensive care stations and its electronic components has been key issue [1-3].**

Wireless sensor networks (WSN) are important in-patient health monitoring and Nodes have base stations, gateway to network with high-performance data processing or storage center with human interface access point and are used as a connection to deliver control information to networks or acquire data in network.Encryption requires complex operations. Detecting and verifying secure locations, establishing keys and establishing trust, attacking sensor nodes, managing security groups, and aggregating security data[1].

In health care, there is an explosive growth of WSN because of technological developments in the networks in medical and low-power networked systems. Challenges and memory limitations, power limitations, processing limitations, size level constraints, and systems are requirements in healthcare. Nodes have base stations, gateway to network with high-performance data processing or storage center with human interface access point used as a connection to deliver control information to a network or to acquire data from the network. These types of nodes have an ability to collect some data and then return it to a sink. Sink communicates with a task Manager. Route by Internet or by satellite communication. Encryption requires complex operations. Detecting and verifying secure locations, establishing keys and establishing trust, attacking sensor nodes, managing security groups, and aggregating security data. In the recent past growth of wireless service networks with IOT has arisen resulting from technological developments in the networks in medical and low-power networked system that has led to expanding quality in several demographic segments in major field studies of human behavior and chronic illnesses. Challenges in memory limitations, power limitations, processing limitations, size level constraints, and systems where requirements are stringent networks are a cutting-edge component of the healthcare industry. This review is an update on Medical sensors, sensors in anesthesia, encryption and futuristic-trends in development of sensors for oxygen monitoring in anesthesia [1, 2, 3]

II. HISTORICAL PERSPECTIVES

In 1980, sensor network research began with Distributed Sensor Network programming extended the Arpanet communication technology (now the Internet) to sensor networks. It spatially distributed low-cost sensor nodes. A sensor network consisted of numerous distributed autonomous sensor units which transmitted information to node made the most efficient use of accumulated data. WSN applications are associated with military and industrial applications that are distant thought from marine life and volcanic activity. WSN technology which then found a place in the home for academic/ scientific research [4]

A graphical representation reflecting end tidal carbon dioxide levels is capnography. It is a verification on correct depth of anesthesia. This is a non-invasive technique. It is reliable, safe, fast, practical, and easy-to-use in an ambulatory patient. A Machine that does estimation is called a Capnogram Plotter. It is a device which can revolutionize mechanical ventilation support. This helps save lives in substantial number of patients who are diagnosed with respiratory distress.

- *Medical Sensors*

Current Medical sensor devices in health care facilities and homes require monitoring of patient's individual status with thermometers, blood pressure monitors. Glucometer, electrocardiograms (ECG), photo seismographs (PPGs), electroencephalograms (EEG's), and imaging sensors that are cost- effective were not available earlier. Cardiac intervention device pacemakers and enabled to measure physiological conditions continually. In aid of a particular signal-processing method, a medical sensor does combine transducers to detect signals of electrical, thermal, optical, chemical, genetic, and other physiological origins. It estimates characteristics indicative of human health. [5]. It is possible to monitor performance in capnography that can improve mechanical ventilation. Such devices are with a small size, light enough, easy to handle and flexible, eventually it will support continuous oxygen monitoring aiding Clinicians using smarter wearable devices which can rapidly and securely record medical data.

III. WIRELESS NETWORKING SENSORS IN CRITICAL MEDICINE AND SURGERY

If a patient is on communication he cannot move freely. More so in an ambulatory condition or a non-traumatic condition or even otherwise. Number of medical errors increase. An SPO2 sensor and pressure sensor are suggested for cardiac patients to monitor blood pressure and oxygen saturation levels. Each patient's sensor data is relayed to smart phones, including the doctors. Even while patients are unconscious, a cloud network efficiently uses monitoring. Intensive Care Unit (ICU) patient needs to be observed carefully. A monitoring system involving usage of huge cables impedes nursing methods and makes complications in patient transfer [4-6]. In the recent past monitoring systems adding wearable and intelligent technologies have dealt with some generalized solutions. It This has not been easy. Detection and classification of versatile vital characteristics should involve application of innovative technologies. **Such devices that use smart and wearable solutions in capnography can be bereft with some technical dilemmas, costs and security domains also have their own share of**

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concerns Application of Sensors in Capnography in Surgical Interventions.

During performance of Capnography, we employ a non-invasive technique.It monitors level of carbon dioxide in exhaled breath (EtCO2). This measures the patient's respiratory status. It is Exhaled CO2 is absorbed by infrared radiation and when it as is aligned to mechanical ventilation system it supports the costal respiratory muscles facilitating specific therapy. This corrects hypoxemia, respiratory acidosis, and patient's health Anesthesia is in itself a drug-induced, reversible condition where the patient remains unconscious and unresponsive to painful surgical interventions. This is artificial sedation achieved by intravenous administration of a mixture of medications including a muscle relaxant with a hypnotic and analgesic drug. With a balance of gas and Intra-venous drugs a quick onset with accurate depth of anesthesia can be achieved. The induction phase it is also pleasant. A short recovery time after surgery is an outcome. Because anesthesia drugs reduce body's metabolism that reduces oxygen delivered to heart, administration of oxygen before induction is essential in airway management. This prevents a low oxygen in blood, Tissues during Apnea or No-normal Breathing in Surgical or stage III anesthesia [6]

- *Types of Wireless Sensors*

We can deploy an Analog and Digital to monitor human body temperature, heart rate, pulse, respiratory rate, and heart rate. These use technologies based on Ultra-Sonic Pressure Infra-Red Radiation while some use thermocouple. Sensors that record Body Temperature based, Gyroscopes, Light-Based sensors, color are touch based sensor devices. When a photo detector emits digital signal, it calculates speed using a disc that is attached to a rotating shaft. A sensor passes through each slot. The readings are displayed on an LCD. A Digital Accelerometer encompasses a variation in accelerom frequency. It shows a square wave and Width modulation. It has an output that is produced vide a PWM signal pulse. Its width remains in direct proportion to its acceleration. [7- 11]

- *Mechanical Ventilation Monitoring*

In case of emergency Ventilators based on pulmonary respiration are capable of facilitating gas exchange in human tissues. They maintain and generate various vital metabolic functions. Respiratory dysfunctions are temporarily, in total or partially substituted using mechanical ventilation. In an operation theater or an ICU, Physicians can designate monitoring support that is capnography through mechanical ventilation. If a patient is subject to cardio respiratory arrest or hypo-ventilation with apnea it is well supported. Elevation in PaCO2 plus respiratory acidosis is avoided. Appropriate depth of Anesthesia during the induction stage ensures make it pleasant with a shortened recovery period post-surgery [4 - 7]. Using a wearable and real-time monitoring system we can monitor vital signs. These are measuring oxygen levels by a pulse oximeter. It is pertinent to observe that 50% reduction FiO2 that is functional residue oxygen can lead to pulmonary atelectasis or even lung lobe necrosis. Establishment of accuracy in anesthesia and analgesia have influence on pulmonary outcomes during the period that a patient is in the Post Anesthesia Care Unit (PACU) after successful surgical outcomes. [12-16]

- *Confidentiality of Data*

Patient health care data is considered under legal and ethical obligations of confidentiality, and disclosed only to physicians or caretaker. Attackers may employ patient data for illegal purpose and it compromises patient privacy. [17]

- *Sensors in General Anesthesia*

Using a continuous flow anesthesia machine, a precisely controlled and constant supply of medical gas (air, nitrous oxide, oxygen,) mixed with an anesthetic vapor (isoflurane) at a fixed concentration to pump it at known pressure and flow rate for balanced anesthesia.

IV. MEDICAL SENSOR SAFETY

Medical sensors collect sensitive body data from a patient and transmit it through wireless channels, become more vulnerable than usually wired networks. Patient physiological variables are personal; they must be protected from security threat.

V. ADVANCES IN MEDICAL SENSOR TECHNOLOGY

Advanced technology new chemical, biological, and genomic sensors and analytics using micro electromagnetic systems, medical -imaging, micro-fluid, and Nano-fluid investigations are in place now thus enabling their quicker detection and personalized type treatment. They have complexity used outside of their medical domains. Recent developments in micro-electronics and computers have created new forms of medical sensing more readily now available to individuals at home, in workplaces, and in living space that evaluate blood pressure and blood glucose. These medical devices have revolutionized the treatment of chronic organic ailments hypertension and diabetes, allowing frequent recording of readings on vitals even before a doctor's visit. Using sensors, we can continuously monitor physiological variables in day to-day life. Use of Holter brand monitors coupled with wearable type heart rate and activity monitors can be artificiality engineered in design, they do record any sudden emergency heart and/or brain event that is in apparent and asymptomatic in a physician's post-surgical round. Geriatric assistance devices and certain implants and prostheses with embedded medical sensors are also becoming available now with an aim of reducing impending undesirable scenarios (epilepsy seizure) or status requiring immediate physical help (brain-controlled motor prostheses). Such a Sensing device should be capacitated be able to communicate and receive power wirelessly. Advances in information technology is now readily connecting medical sensors to other devices but early sensors were by and large isolated using built-in user interfaces with displayed readings. It is possible to connect a sensor to an external device through wired interfaces like RS 232, USB, and Ethernet. Sensor-based devices are being integrated into patient is away from home and engaging in outline tasks. Now this is

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on real-time medical imaging. With Wearable devices and ambulatory sensors, wired or wireless connection may be connected to cloud computing. These sensors do record patient data in non-volatile memory. This can later be uploaded and further shared with doctors for further analysis. Also, sensor technology is more sophisticated using the development of cheap, small, high-quality sensors even in personal and also advanced machine learning algorithms which are capable of analyzing complex conditions such as stress. The caregivers should be informed about depression and addiction derived from sensory sensor information. Development of internet connectivity enables information and rapid response [18].

With use of sensor networks communication from sensor node to the sink lots of energy is consumed. Clustering is being suggested with a strategy for providing communication-within sensor networks in an investigation Gupta et al, [19] have proposed a clustering procedure for reduction in energy consumption that reduces delay in communication, improves connectivity in network. It makes use of an algorithm to improve performance and lifetime of the networks. During the Sars Covid 19 pandemic a myriad of social distancing practices such as limitation in travel with exercise in control over borders along with closure of social events in bars, clubs was recommended. During recent times models was developed to automatically detect a class of population that was based on deep neural networks. It made use of CCTV cameras, These tracked and measured distance between two humans. It also performed real-time threat assessment based on statistical analysis of human movement data. It investigated behaviors. It documented extent of social distancing violations. It identified areas of high-risk [20] Threats in Information Transit can occur if sensor data is being sent (in transit). SHIMMER is an embedded micro-controller with very low-power radio with a consumption of about 60 mW, design allowing a small and rechargeable battery to last for hours or days together. Software is designed with resource limitations because of a lack of memory and computing power and wireless have limited bandwidth. Sensor nodes balance computing and communication overheads. Use of a Smartphone-based system has great computing power. A shorter charge cycle limits types of apps that a smart-phone can support. The topology in a network may change over time, because of node mobility, environmental changes in RF medium and results in an unpredictable amount of power consumption pattern.

WSN device mobility that has its own SR responsible to configure and manage an aggregated device with an exemplary WSN movement was innovated as RFC3963. This was a research effort by a working group NEMO in 2005. Privacy issues to collect information have it, transferred and processed by WSN has received minimal attention. Effective defenses against exposure of data and context private information are an essential requirement.

VI. IOT-BASED WEARABLE SMART HEALTH DEVICE SOLUTIONS FOR CAPNOGRAPHY

In a study by Ahmed et al [21] s they deployed IOT based healthcare system, these enabled with an automated digital architecture. This aimed at providing physicians with data on patient’s health status in remote. This monitored support and thus made these systems affordable and practical. In another investigation, Dusarlapudi et al. [22] made a hypothesis with a system employing IoT and Telemedicine using unsupervised machine learning techniques. It collected data and reported the patients’ health condition employing a support vector machine algorithm. It was designed to quantify patient data while producing a deviation representation. It also plotted graphs using Language Python. In a different prototype [23], a protocol was made with integration of sensors in an efficient, safe, and scalable way employing signal elimination, data calibration, and real-time monitoring. Its purpose was to employ an architecture that contributed effectively in perception and identification of problems in healthcare services was its primary mission.

VII. FUTURISTIC AREAS OF RESEARCH AND DEVELOPMENT IN CAPNOGRAPHY WITH IOT.

During applications in current medicine use of flexible sensors will substantially reduce cost of performing capnography. Utility of IoT Blynk platforms may assist in providing an ability to integrate and develop devices powered with remote and real-time management. Nowadays a fast-monitoring system that enables robust, dynamic and effective 3D prototyping technology has been made available. This gives excellent alternatives in device development. It is an “emergency” device; It was widely used in the COVID-19 pandemic. It had a low cost.

In the near future we can expect introduction of flexible and intelligent monitoring systems. These can promote evolution in positive mechanical ventilation thus supporting and innovating healthcare systems. Later it will have impact e-Care applications as well.

VIII. AI-ML INTEGRATION TO WSN DEVICES AND THEIR ROLE IN PREVENTIVE CARDIOLOGY

In medical Diagnosis and Prognosis Prediction encompasses identification of medical events that may be in future occurrence. It may provide crucial medical information that can help to prevent progress to chronic medical complications.It can even support a diagnostic and prognostic medical decision. The medical parameter Respiration rate (RR) is a fundamental physiologic parameter. In patient’s observation use of non-invasive technology for measuring blood oxygen saturation is applicable in wearable devices by employing a Finger. It can be used often to estimate blood oxygen saturation levels. By using mobile connections, we may lead sensors to independent and wearable devices. In recent developments technology has permitted adjustment in sensor parameters that can refine depth in tissue measurements. It has better

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function in clinical applications. Capnography is widely accepted in clinical settings as an integral part in anesthesia care allowing anesthesiologists evaluate the level of consciousness in a patient in sedation. Under use of capnography has high correlation with morbidity and mortality in aIntensive care unit. It is a routine monitor for cardiac output and ventilation. We must remember however that continuous capnography and pulse oximetry are with limitations. Use of continuous monitoring in non-intubated patients may occurr as a result of artifacts that can falsely trigger alarm systems in monitors that clue endangers in patient safety. ML and AI accurately analyze capnography data but dealing imbalanced datasets remain. Respiratory depression is infrequent representing irregularities in a regular breathing pattern leading to an inherent class imbalance that can bias ML models [24.]

IX. CONCLUSIONS

Capnographic devices enabled with IOT and AI are contributing in mechanical ventilation and its monitoring in critical and regular clinical practice. AI and ML alogarithms can identify risk factors for hypoxia, allowing interventions. ML models analyze ECG and other cardiac vital signs to predict ventricular arrhythmias and cardiac arrest before documentation of clinical symptoms. WSNs coupled with Big Data have capacity to overcome limitations and now we may anticipate emergence of new heterogeneous datasets. The basic intention is that even if a surgeon or anesthetist is not exactly present physically, precise volume of of anesthesia gas prescribed to obtain the exact depth can become truly predictable. This can create variations in anesthetic levels during surgeries. **By using Smart algorithms accurate detection of abnormal ventilation is detectable which permits timely medical intervention well before patient health deterioration. Current research** has built upon an extensive data set in continuous monitoring of end tidal carbon dioxide levels and oximetry measurements that are sourced from clinical settings across the globe. Combining AI with automated external defibrillators has potential in detecting abnormal rhythms preceding cardiac arrest. **To conclude, use of deep learning studies coupled to a state of art AI-ML technologies are demonstrating promising guidelines for future studies to follow on IoT-based wearable devices applicable in capnography and oximetry aimed at preventing cardiac arrests during medical and surgical interventions.**

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