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IoT-Based Smart Monitoring Solutions for Cancer Patient

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Abstract—Integration of related technologies has launched new opportunities in contemporary healthcare, especially in the. management of critical diseases such as cancer. The Internet of Things allows patients to be constantly monitored by linking. sensors, platforms in the cloud, and wearable devices, enabling. Access to real-time medical information by healthcare professionals. This capability helps with early diagnosis, early intervention, and improved treatment outcomes.

In this paper, an Internet of Things-based smart monitor is presented, a tracking system with the aim of helping to care for cancer patients. The proposed approach brings together wireless sensor networks and cloud computation. In order to store and manage data, transmit specifics, and analyze patient health information efficiently. Remote monitoring that will be made possible by it will allow the company to monitor systems, lessen the need to visit the hospital regularly, and improve quality of care in general.

The paper also looks at system architectures and so on. Illustrates the ways in which Internet of Things technologies can be effectively operated in health-related facilities. The findings suggest that integrating the Internet of Things with data analytics can significantly improve decision-making and patient manage- ment. This work contributes to the development of intelligent healthcare solutions based on providing reliable and accessible cancer care.

The topics covered include the Internet of Things, cancer care, healthcare systems, patient monitoring, and smart devices.

I. Introduction

The concept of modern-day development has recently changed because the Internet of Things creates links and allows different smart instruments, electronic items, information, and offerings to work together. [1] Many people believe that the Internet of Things brings huge changes to global production and how humans live together because the Internet of Things makes tasks faster, lowers the cost of activities, and allows medical professionals to share information immediately, which improves how sick people are helped. Continuous links between machines and humans throughout the world are provided by the Internet of Things. [2][3] Knowledge about the opportunities and benefits of the Internet of Things within medical solutions remains vital to sustaining people alive and helping people feel more content while using smart-linked instruments.

The advancement of modern technology has been significantly influenced by the Internet of Things, which enables communication between devices, systems, and services through interconnected networks [1]. This connectivity has influenced many industries in the sense that it maximizes efficiency, reduces operational expenses, and improves the faster exchange of data. Within the field of healthcare. The Internet of Things is especially important because it enables medical experts to retrieve information about patients in real time, resulting in more effective treatment and care. Furthermore, constant communication between devices and users has provided the possibility of tracking health conditions remotely, improving overall quality of life. The increased use of the Internet of Things in the medical domain emphasizes its role in providing smarter and more reliable medical solutions [2][3].

As the latest innovations show, contemporary cars are becoming more and more autonomous due to the application of embedded sensors and the smart control system. When these self-driving systems are combined with other existing transportation networks, it will be possible to make the roads safer and improve traffic management systems. Similarly, this paper examines system models that help in the provision of intelligent services in fields like public safety and healthcare monitoring. This type of system may be a solution to detect cancer and data-driven healthcare analysis platforms [10].

Such strategies are more likely to raise living standards by improving the efficiency of medical services. An aggressive

healthcare system is capable of achieving improved patient outcomes through the facilitation of early intervention and follow-up. In this regard, it is highly suggested to use the Internet of Things in treating cancer, as it will enable data collection and analysis in real-time. Cloud computing combined with the Internet of Things improves overall health care management by allowing secure storage, processing, and access to health care information [13].

These systems have been created by the investigators that integrate sensors and smart connected devices to enable rapid detection and monitoring of cancer. Using the Internet of Things in the medical field can improve patient health by transforming gigabytes of medical data into useful information to make clinical decisions [11][9]. These systems allow healthcare professionals to deliver more precise and effective care by allowing them to use data as a driving force behind their treatment choices. As a result, Internet of Things-based solutions have the potential to enhance the overall effectiveness of healthcare services.

Wearable Internet of Things devices are created in such a way that they can be used as a part of the human body, so these devices will be able to monitor one's health on a constant basis. Their performance has been enhanced due to developments in technologies like edge computing, which enables them to process data faster and with less latency. These devices are significant in contemporary healthcare because they allow immediate monitoring of the individual's health issues. This paper presents the importance of wearable devices in the healthcare services of the Internet of Things and explains the principles of designing mobile sensors and network infrastructures [14].

The project will focus on creating an intelligent, smart and integrated Internet of Things based cancer treatment system. The suggested framework provides a framework that can be implemented in different implementation settings [15]. This approach takes into account several phases such as System design, execution, and the actual operation in the real world to ensure that the functionality is effective. The step-by-step approach of the model offers a feasible basis to develop scalable and effective healthcare solutions.

The architecture suggested has been thought through with a view to attaining flexibility and security by explicitly stating its key building blocks and how they relate to each other. Although there is literature on the application of the Internet of Things in health care, most of the investigations are confined to generic medical applications. It has slightly less focus on its direct contribution to improving disease-specific treatment, especially when it comes to controlling cancer [18].

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II. LITERATURE REVIEW

Research papers published within the last 10 years were thoroughly analyzed in order to get a clear picture of the way the Internet of Things has been used in cancer research. The sources of information were identified on Google Scholar, which is a popular online service of peer-reviewed journals, conference proceedings, and research articles. The search was conducted with the following keywords: "Internet of Things" OR "Internet of Things" AND "Cancer" [7][9], and it was possible to find relevant work related to the sphere of cancer detection, monitoring, detection, and treatment.

The information gathered from the search results was then utilized to extract various insights about advancements in this field of study. [9] One of the significant findings based on the gathered data is the yearly trend of articles focusing on the Internet of Things applications related to cancer. This pattern aids in comprehending how scholars' interest in this field has changed throughout time.

Fig. 1 shows the process of literature selection. The search results were first retrieved on the database and then a screening process on the database to eliminate duplicate and irrelevant studies. Articles that only had an indirect relation to Internet of Things-based approaches to cancer research were viewed as not worth further analysis. The identified studies were, in turn, analyzed to find patterns of publication and the focus of studies among the different types of cancers that were addressed with the help of Internet of Things technologies.

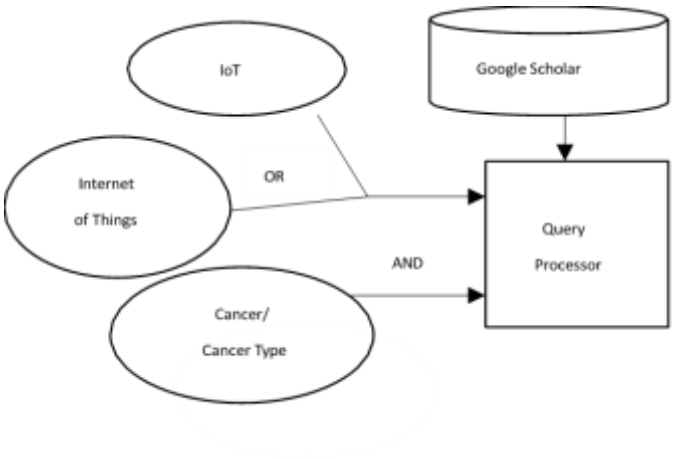

Fig. 1. Methodology of literature review.

The initial developments of the Internet of Things did not have an immediate effect on cancer investigations, and the first studies in this field were scarce. The first notable publication was published just a few years later than the introduction of Internet of Things technologies, which shows that this interdisciplinary area was slow to develop. In the past, there was a relatively lower number of publications, indicating a low level of research activity. Nevertheless, since approximately 2018 [14], the number of research studies on Internet of Things-based solutions for cancer-related healthcare has been increasing. This significant increase in interest indicates that scientists have begun to appreciate the opportunities offered by

the Internet of Things to improve patient monitoring, assist with early diagnosis, and enhance healthcare management systems.

Although research on Internet of Things applications in cancer care has been growing in the past few years, the amount of studies that primarily address the topic is relatively small in contrast to other healthcare fields [10]. It means that the field is only underdeveloped and has a lot of potential in the future research and development.

In order to filter the search results to the research on particular types of cancer, the search strategy was narrowed down by adding the name of each cancer and Internet of Things-related terms. To illustrate, the keywords like ”Internet of Things” and ”breast cancer” were entered to find related articles. By doing so, the number of studies in various tumor types was estimated. The data obtained, as summarized in Figure 2, shows the distribution of publicly published content over the years. The initial research activities concentrated on the investigation of cancers like thyroid, prostate, and cervical cancer, especially after 2014. In subsequent research, other forms of cancer were investigated, suggesting a slow increase in research focus in this field.

The review of existing studies indicates that the overall number of publications on Internet of Things-based medical management for different cancers is relatively low, with an average value of around “2.” This indicates minimal research in this field. Specifically, any scarce and insufficiently recorded literature pertaining to cancers like leukemia, stomach cancer, pancreatic cancer, and kidney cancer is minimal. The shortage of the research indicates the gap in the literature and the necessity of conducting additional research in the given areas.

The studies published within the past decade offer a summary of the emerging connection between the Internet of Things technologies and the applications of the technology in cancer contexts. Much of this research had largely centered its attention on cancers like pulmonary, breast and thyroid cancers meaning that there were more interest in conducting research in these fields. These groups add a significant proportion of the total publications, and the majority of other types of cancer are under-investigated, and the research activity is limited. This imbalance shows that there is much more to explore in various areas of cancer. Table 1 summarizes the key studies to be used in this review.

III. IoT-Based Cancer Types

In this section, the recent studies on application of IoT technologies to various types of cancer have been summarized.

A. Internet of Things and Cancer of the Lung

The Internet of Things (IoT) is now a significant technology that is used in various fields such as healthcare and smart infrastructure. The IoT systems can be used in the medical setting to facilitate the optimization of processes by shortening waiting lines, facilitating continuous monitoring of patients, and enhancing cooperation among the staff. They also aid in effective inventory management and help in managing critical medical equipment. Also, IoT solutions help to make the life of people with disabilities easier, including the devices that help people with hearing impairment and improve communication with the environment.

Research like that by Palani et al. [11] has discussed IoT-based systems to monitor and enhance healthcare services continuously. In their method, they use classification techniques to forecast lung cancer using medical images. A fuzzy clustering method is used to segment the images into meaningful regions, improving the accuracy of detection. Further image processing, such as edge detection and morphological operations, is carried out to find the applicable features and affected regions. This methodology will show how IoT and state-of-the-art image analysis can assist in more accurate diagnosis.

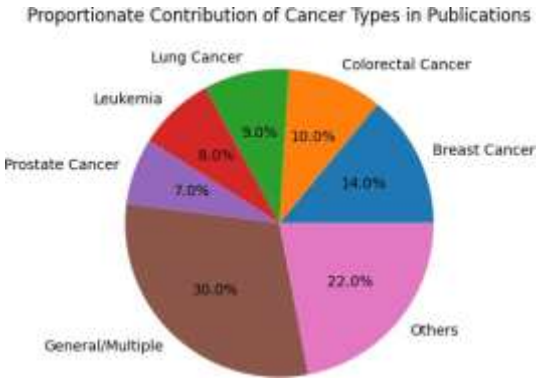

Fig. 2. Study the percentage of each form of cancer.

Smart healthcare is a new interdisciplinary area that has emerged as a result of the incorporation of computational methods into medical science. The primary goal of the strategy is to offer individual attention to patients that will be available whenever and wherever. An illustration of this is the application of computer-assisted treatment plans, in which patients and healthcare professionals combine their efforts to develop appropriate treatments. In addition, artificial intelligence, edge computing, and cloud platforms, among other advanced technologies, are being integrated into standard medical practice to improve both diagnosis and treatment procedures, including their use in areas such as traditional Chinese medicine.

Liu et al, study [6] highlights the importance of early detection in improving lung cancer outcomes and discusses the application of deep reinforcement based learning to their diagnosis. Their work describes modern-day issues and partnerships and how sophisticated models of learning can be used

to facilitate the switch to intelligent and automated healthcare systems in the Internet of Medical Things (IoMT).

Moreover, Pradhan and Chawla [13] surveyed several studies, which used machine learning in disease prediction. Through their analysis, they have shown how such approaches can be applied in the healthcare setting of the IoT, especially in the case of lung cancer detection. The study compares various machine learning methods, giving insights into their success in enhancing treatment decisions and patient survival rates. It also points out the possibility of advanced models such as deep reinforcement learning to improve the accuracy of the diagnosis.

There is evidence that visual and audio-based diagnostic systems are capable of identifying abnormalities in a relatively short time with high accuracy (experimental studies). Machine learning algorithms have been extensively utilized on CT scan images and assist in prediction activities in the case of lung cancer. The image classification methods are usually divided into two broad categories: supervised and unsupervised learning.

Disease prediction uses various types of data, both sensor-acquired and clinical data collected by hand. More recently, a digital twin of a patient has attracted attention, with a virtual representation of a patient generated based on IoT data and artificial intelligence in order to aid in health monitoring and making clinical decisions. This practice will become significant in more advanced network environments in the future like the 6G.

To provide security in such systems, it is important to have robust protocols and protective measures, especially by use of smart sensing devices [11]. Currently, the applications of digital twins in the healthcare sector have been concentrated on uncovering vulnerabilities of the system and enhancing the data management procedures. Moreover, the use of deep learning has been on the rise to address the limitations of the conventional machine learning methods, particularly in medical diagnosis.

To achieve the security of the medical digital twin systems based on the IoT, it is crucial to comprehend the software implementation and determine vulnerabilities. It is also significant to assess cyber preparedness in the actual healthcare settings, particularly with the sophistication of massive smart medical systems. When combined with IoT, cloud computing allows remote monitoring of patients in that they offer scalable storage and processing capabilities. This collaboration can be used to address the constraints in terms of data management and computing resources, which will guarantee efficient and dependable healthcare services.

Internet of Things (IoT)-enabled cloud-based systems are increasingly becoming relied upon in the medical sector to facilitate the creation of new medical products and services. In lung cancer, many deaths are experienced as the disease is not diagnosed at an early age which underlines the difficulties of ensuring that the disease is diagnosed in time. Early diagnosis of cancer is a challenging issue because of its problematic nature and the inability of current screening techniques to do so. Most of the time patients are wrongly classified and some are already at an advanced stage when the condition has already developed. To solve this problem, a support vector machine (SVM) classifier can be tuned to achieve a better accuracy and reliability to create an IoT-based system of lung cancer assessment.

It is gaining more and more acceptance that computer-assisted diagnostic systems could assist clinicians in detecting abnormalities earlier and enhance decision-making. Machine learning is a prevalent method used in the studies of lung cancer to process the images of the chest CT and identify the patterns that might be related to the disease. Classification methods of images can broadly be categorized into supervised and unsupervised, depending on the mode of training of the models. In one of the studies conducted by Onasanya and Elshakankiri, the authors investigated the use of cloud computing to handle cancer-related information and enhance access to diagnostic and treatment information, and also integrate IoT technologies in the provision of healthcare. Combining these platforms with the IoT-related data analytics, healthcare delivery professionals and medical devices manufacturers will have the opportunity to explore information gathered by multiple interconnected devices and sensor networks to improve patient care.

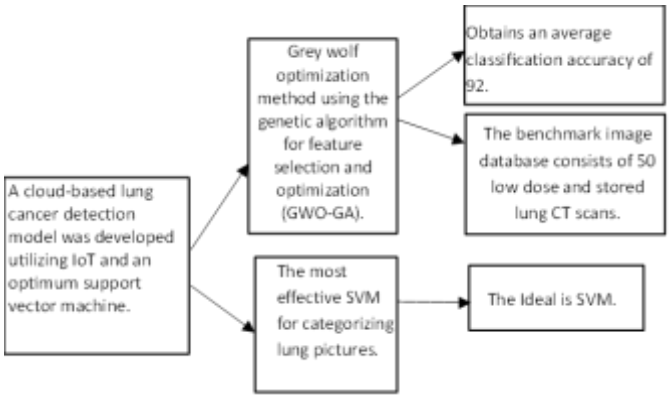

Fig. 3. IoT-Enabled Lung Cancer Prediction.

B. Ovarian Cancer and the Internet of Things

The technology of the biosensors is advancing rapidly particularly in the detection of key health indicators in a more convenient and expedient manner. An example of this is the blood marker of HE4 which can be used to diagnose diseases early on. In this arrangement, a portable potentiostat and a Wi-Fi cloud system (IoT-based) are connected to record signals. Such signals are detected with enzyme-labeled magnetic elements and are recorded with the help of differential pulse voltammetry. The system operates through a calibration and real measurement switching, thereby assisting in gathering information more effectively. The calibration is initially adjusted

TABLE I
A CONCISE OVERVIEW OF THE WORK THAT HAS A CONNECTION TO CONDUCTING ASSOCIATED STUDIES.

References	Technology Applied	Type of Cancer	Remarks
Valentina Bianchi et al., 2020. [1]	IoT-enabled portable electrochemical immunosensor with self-calibration.	Ovarian Cancer	Developed a portable sensing device capable of accurate biomarker detection using automatic calibration mechanisms.
Jing Cui et al., 2021. [2]	Smart temperature sensing system for basal body monitoring.	Thyroid Cancer	Proposed a system that combines sensor data with digital processing to support clinical decision-making.
Elkoughi et al. [4]	Bio-heat microsensors with OpenCV and scripting tools.	Breast cancer	Introduced a diagnostic approach using highly sensitive bio-heat sensors for early detection.
Han et al. [5]	CNN and BAS - algorithms	Breast Cancer Recovery	Developed a model to assist doctors in planning personalized diet and therapy programs.
Liu et al., 2019 [6]	Intelligent sensors with deep reinforcement learning.	Lung Cancer	Applied advanced learning models to improve accuracy in cancer detection.
Memon MH et al., 2019 [7]	Recursive Feature Selection (RFS) algorithm.	Breast Cancer	Enhanced feature selection efficiency for better prediction performance.
Onasanya A et al., 2019 [9]	IoT and Wireless Sensor Networks.	General Cancer Care	Addressed secure data transmission and privacy in healthcare systems.
Palani S et al., 2019 [11]	Fuzzy C-Means clustering for image segmentation.	Lung Cancer	Improved prediction accuracy through advanced image classification techniques.
Pradhan K et al., 2020 [12]	IoMT with cloud-based analytics.	Lung Cancer	Enabled continuous patient monitoring using connected medical devices.
Savitha V et al., 2020 [14]	IoT with neuro-fuzzy systems.	Breast Cancer	Neuro-fuzzy techniques are being combined with the Internet of Things (IoT) to achieve a high level of accuracy in predictive statistics.
Zhang J et al., 2020 [17]	Digital Twin in healthcare.	Lung Cancer	Simulated patient conditions using virtual models for better diagnosis and monitoring.

and set with the help of a simple method. Then, a calibration curve is constructed using the data collected. A four-parameter logistic model is then used to fit this curve in order to make the final results closer to the truth.

The calibration values with this system are transmitted to the cloud and are subsequently utilized to approximate the concentration of the unknown samples as well as to undertake reverse predictions when necessary. In order to minimize the amount of power used, a portion of processing, e.g. calculation of concentration and interpolation in the calibration process, is performed directly on the device rather than entirely relying on the cloud. Ovarian cancer is a severe condition that occurs in the ovaries and which is usually not easily detected in its earlier phases, thus putting people at risk of death. The Internet of Medical Things (IoMT) provides an opportunity to enhance the detection process through connecting medical devices and making it possible to monitor data continuously. The data of ovaries cancer is processed in this method with the help of the optimized recurrent neural networks and self-organizing maps. SOM technique assists in distinguishing helpful use patterns of huge medical data and aids in the choice of the most valuable features, which enhances the overall model performance.

The optimal recurrent neural network (ORNN) is also another technique of classification. To improve the precision of ovarian cancer diagnosis, this model is combined with an adaptive harmony search optimization (AHSO) technique. The optimization process is used to fine-tune the model in order to enable it to classify the cases better. In order to evaluate the approach, they conducted several experiments based on the information gathered on women who are believed to be at high risk of ovarian cancer and particularly women who have a family history of the disease or those who have a history of cancer in the past. The outcomes can be used to explain the performance of the model in detecting possible cases.

C. Internet of Things and Thyroid Cancer.

Thyroid cancer develops as a result of the abnormal growth of cells in the thyroid gland which is found just underneath the Adam's apple in front of the neck. The gland is found deep in the neck; hence, it is seldom felt externally unless it is large or when it is examined through the use of medical imaging procedures.

Thyroid cancer is generally classified into two broad categories: differentiated thyroid cancer and medullary thyroid cancer. Amongst these, differentiated thyroid cancer is the more prevalent and can be treated and managed more easily once it is diagnosed.

To diagnose thyroid cancer, a number of diagnostic techniques are employed, which include a laryngoscopy, hormone level testing by analyzing the blood, ultrasound, and CT scans. Moreover, such a system as IoT-based medical care has also been suggested by researchers such as Cui and others to aid in the evaluation of the risk posed by thyroid disorders with the help of connected medical technologies.

IV. IOT-INTEGRATED CANCER CARE

Internet of Things (IoT) is not a new technology, but it has evolved into a significant technology that has a tremendous

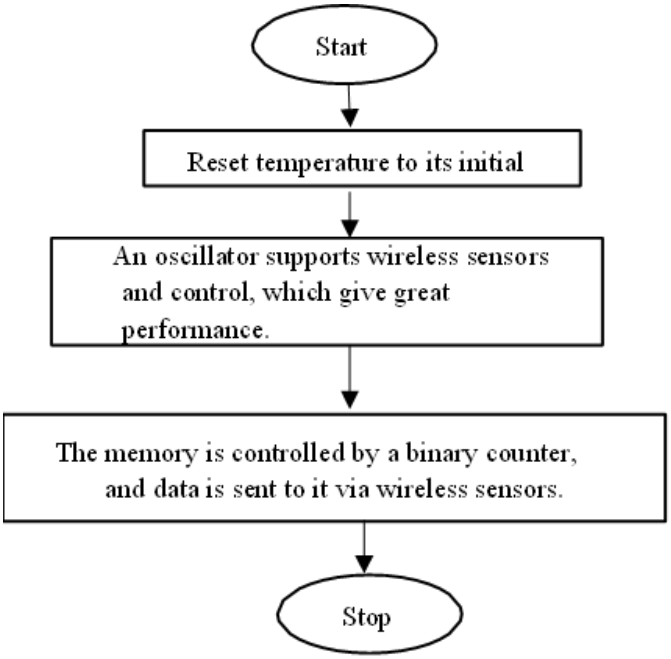

Fig. 4. IoT-powered medical system for thyroid cancer.

impact on our daily life. It has been widely used in other areas, such as education and healthcare, and has grown rapidly over the years. IoT can be used in medicine to assist cancer patients with uninterrupted monitoring and improved support in their treatment, as well as real-time monitoring of body conditions, including the side effects of medical treatment, such as radiation.

Another direction that researchers have used in treating cancer is the application of the knowledge acquired in the use of IoT in other fields. The advances have helped in enhancing patient care and treatment planning. The general system design may be perceived as the following channel arrangement:

1. Various IoT devices gather patient and environmental data, and the data is significant to enhance healthcare services. The information derived through these devices can assist physicians to make informed decisions regarding diagnosis, early diagnosis and treatment.

2. Data Center Layer is the layer that handles the data collection and storage of smart devices received data. This stored data is then applied to aid various medical interventions and healthcare procedures.

3. This layer handles the interaction between various healthcare services, such as pathology labs, imaging centers and medical professionals. It assists in making sure that patients have consistent and well-coordinated treatment.

4. This layer improves the interaction between patients and medical devices due to the visual feedback. It uses IoT and smart technologies to enable these features. Patients will be able to receive necessary services even in areas where there is low network coverage.

5. It is their primary job to safeguard patient information, medical records, devices and any communication in the system.

V. Observations

Although technology offers several benefits for healthcare professionals and patient identification, there are still many challenges that need to be resolved. A few of these issues are outlined below.

The first one is the lack of government policies.

- Few conditions of the right one.
- Communication protocol incompatibility.
- Security and hardware vulnerabilities.
- A variety of devices are available.
- Data encryption and data masks are controlled by third parties.
- The power usage of individual appliances ought to be determined.
- The network contains a reliable communication channel amongst the nodes.

The ultimate goal of the research community will be to further study this area in details in order to realize the maximum potential of the IoT in healthcare.

VI. Conclusion

This paper has discussed how the Internet of Things technology can be used to monitor cancer patients and assist healthcare systems. A comprehensive review of the available literature on Internet of Things-based solution of cancer care, particularly lung, ovarian and thyroid cancer management was done. The results demonstrate that the Internet of Things can be used to enhance patient monitoring besides alleviating the burden of medical professionals. Even though there is still limited research in this area, it is anticipated that this area of research will increase upon the development of related technologies. The future research will be aimed at using artificial intelligence and blockchain to improve cancer patient care.

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