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Review

Recent Developments with Biosensors in the Diagnosis of Cancer Diseases

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ABSTRACT:

Aim: Early diagnosis is very important in cancer diseases. Our aim in this study is to reveal the latest developments in the studies on the use of newly developed biosensors in the early diagnosis of cancer diseases.

Material and methods: For this purpose, the results obtained in studies using different methods and materials in different types of cancer were evaluated. The sensitivity and specificity rates obtained with biosensors in the diagnosis of cancer were compared with the results obtained by conventional methods.

Results: According to the results obtained in studies conducted with biosensors, the diagnosis of cancer diseases can be made with biosensors in a cost-effective way, in real-time, with much higher sensitivity, specificity and selectivity than conventional methods.

Conclusion: According to the findings we obtained in our study, biosensors have opened a new era in the diagnosis of cancer. Early diagnosis of all kinds of cancer diseases will be possible with this method and mortality will be decreased to very low levels.

KEYWORDS: Biosensor, early diagnosis, cancer disease.

1. INTRODUCTION

Cancer diseases are the second cause of death in the world [1]. Early diagnosis in cancer diseases is the most important factor reducing mortality rates [2, 3]. Due to the fact that most of the conventional methods used in the diagnosis and screening tests of cancer diseases are not effective in the early period, expensive, and not easily accessible; mortality rates are still high [4, 2]. Especially in studies conducted by scientists, non-invasive molecular marker tests, advanced imaging methods, artificial intelligence-supported advanced diagnosis methods, have rapidly increased the diagnosis rates of early cancer and precancerous lesions and significant decreases have been achieved in mortality rates [1, 4]. Although most of the conventional cancer diagnostic tests available for early diagnosis of cancer diseases are expensive, low sensitivity, require special technical personnel and are time-consuming tests.

Biosensors have many advantages such as high sensitivity and specificity, portable, low cost, effective in many cancer types and real-time. While conventional diagnostic tests can detect the presence of 1 billion malignant cells in tumor tissue with a diameter of only 7-10 nm, optical biosensors can detect several million malignant cells [5, 6, 7]. Especially with the development of microfabrication technology, biocompatibility, field enhancement and 2-dimensional materials that provide higher surface-volume ratios, significant successes have been achieved in the early diagnosis of cancer and some other diseases[5].

Biosensors are devices that analyze and detect signals from biological structures such as DNA-RNA-protein and convert them into electrical or digital signals. New generation 2D biosensors have great flexibility and wide application areas [8].

The most commonly used nano-material-based biosensors for the detection of biomarkers in cancer diseases are: colorometric biosensors convert chemical or biological reactions into color signals.

However, their sensitivity and specificity are relatively low. The sensitivity and specificity of fluorescent biosensors are extremely high. Successful results are obtained in the diagnosis of cancer biomarkers with Surface-enhance Raman scattering-based biosensors designed in recent years. With surface plasmon resonance based biosensors, biomarkers in many cancer types such as PSA, VEGF and BRCA can be detected with great sensitivity.

Electrochemical biosensors are used as effective signal transducers in the diagnosis of cancer biomarkers. In addition, biosensors such as electromagnetic meta-material-based biosensors and Label-free photonic crystal refractive index biosensors used in the diagnosis of cancer biomarkers have been developed in recent years [9].

2. MATERIALS AND METHODS

2.1. Recent Advances In Biosensors In The Diagnosis Of Cancer Disease

In addition to the advantages of biosensors in the early diagnosis of cancer, such as high selectivity and specificity rates, low cost, and rapid results, one of the most important advantages is their high miniaturization features. Especially nanosensors using different nanoparticles are ideal for these applications. In colon and lung cancers, which are among the most common causes of death in the world, early diagnosis will be possible in the very near future, with low cost, in a very short time, with continuous monitoring of body fluids, especially with miniature biosensors using electrochemical methods [10]. Early diagnosis can be made by detecting biomarkers in many cancer types with the highly sensitive and effective paper-based biosensors developed in recent years. The noninvasiveness and low cost of these methods will lead to their more frequent use in cancer screening in the near future [11]. Metal-organic frameworks, which emerge as porous crystal materials, are used as electrochemical-based biosensors in the early diagnosis of cancer by enabling the detection of mRNAs, living cancer cells and biomarkers due to their ultrasensitive properties, as well as areas such as energy and environment [12]. Shariianjazi et al., in their study, showed that nano-material-based nanobiosensors are excellent tools in the early diagnosis of cancer disease at the molecular level, and that newly developed quantum dots, upconversion nanoparticles, inorganics such as ZnO-MoS2 and metal-organic frameworks and it is very effective in the diagnosis of diseases such as lung, colon, prostate and breast cancer was reported [13].

Aptamers are oligonucleic acids that can bind to specific target molecules and are also found in the structure of miRNAs. Due to these features, aptamer-based biosensors have been developed that enable early diagnosis with high sensitivity and selectivity in all cancer types [14]. With newly developed L-tryptophan-based electrochemical potentiometric aptasensors, the sensitivity limit in cancer diagnosis has been increased to 6.4x10-11 M[15]. In a study by Lu et al., it was reported that plasmon-enhanced biosensors are very effective for the analysis of microRNAs, which are very important biomarkers in the early diagnosis of cancer, and the most important reason for this is the hypersensitive properties of plasmons [16].

An ultrasensitive electrochemical biosensor for the detection of MALAT1 lncRNA, which is effective in the diagnosis of non-small cell lung cancers, was developed by Chen et al. A gold nanocage combined with a decorated screen-printed carbon electrode (SPCE) was used. Thus, a ripping new method has emerged in the early diagnosis of cancer with low detection limit (42.8 fM), stable, wide linear range (10-7-10-14 M), excellent biocompatibility and conductivity due to its large surface area [17]. In a study by Syed et al., it is possible to detect circulating tumor cells with high sensitivity in a short time with electrochemical and label-free biosensors in lung and prostate cancers, which are the most common causes of cancer death in men, however it may take time for this advanced cancer diagnosis method to apply clinical practice, as it requires billions of dollars of investment was reported [18]. With the [Fe(CN)6]4-/3-redox system electrochemical biosensor developed by Boriachek et al., it has been shown that it is possible to detect miRNA-21, which is one of the most important molecular markers in the early diagnosis of colon cancers, with a superb sensitivity of 1.0 pM. Graphene is a 1 atom thick carbon structure and is an ideal biosensor material due to its exceptional physicochemical properties. Graphene has high electrical and thermal conductivity, optically transparent, has increased chemical and mechanical strength, and for these reasons, graphene can obtain a very large surface area. Because of these features, when they are used in biosensors for cancer diagnosis; it can be easily designed, micromachines can be made, and high sensitivity, specificity and selectivity can be achieved [20, 21].

In a study by Mostufa et al., .it was reported that early diagnosis can be perform with very high sensitivityTiO2/Au/Graphen-based surface plasmon resonance biosensors in 6 different cancer types (breast (MCF-7 cell), breast (MDA-MB-231cell), skin, leukemia, adrenal gland, cervical) [22].

The specificity of serum PSA measurements, which is the most commonly used biomarker in the diagnosis of prostate cancer, is quite low. Therefore, diagnostic methods with higher sensitivity and specificity are needed for the early diagnosis of prostate cancer, which is one of the most common types of cancer in men. With DNA-linked nanoprobe biosensors developed by Kshirsagar et al., it is possible to detect miRNA-21/miRNA-141/miRNA-375 panel molecular markers, which can provide correct results in a single step in the early diagnosis of prostate cancer, with high sensitivity and specificity, without the need for PCR tests. and in vitro [23]. Cervical cancer is one of the most common cancer types in women, with a mortality rate of 50%. With a thoroughly computerized method developed by Baabuc et al., it has been shown that the levels of miR-21-5p and miR-20a-5p, whose expression is increased in serum in cervical cancers, can be detected with high sensitivity and specificity with a biosensor [24]. In a study by Uygun et al., it was shown for the first time in the literature that circulating tumor DNA could be detected label-free with high sensitivity and specificity using impedimetric biosensors powered by CRISPR-dCas9 [25].

As seen in the studies we analyzed in our study, biosensors are rapidly taking their place in the medical world, opening a new era in the early diagnosis of cancer diseases.

4. CONCLUSIONS

According to the results we obtained in our study, it will be possible to detect specific molecular markers to be investigated according to the type of cancer disease in all types of cancer in the near future with an extraordinarily high sensitivity, specificity and selectivity with biosensors and it will be possible to detect them at the very early or precancerous stage, and mortality will decrease to minimal levels. However, huge investments are required to offer this new technology into the service of humanity worldwide.

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