American Journal of Biodiversity
https://biojournals.us/index.php/AJB
ISSN: 2997-3600

Harnessing Genetic Engineering and Biotechnology for Personalized Cancer Treatment: Innovations and Challenges

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Received: 2024, 15, Dec
Accepted: 2025, 21, Jan
Published: 2025, 28, Feb

Annotation: This study explores the integration of genetic engineering and biotechnology for personalized cancer treatment, addressing the growing demand for targeted and effective therapies. Despite significant advances, a knowledge gap persists in optimizing genetic modifications to enhance treatment efficacy while minimizing side effects. This research utilizes next-generation sequencing and CRISPR-Cas9 technology to identify genetic biomarkers and develop personalized therapeutic strategies. Findings reveal that precision medicine enabled by genetic profiling significantly improves patient outcomes and reduces adverse reactions. The results underscore the potential of personalized cancer treatments to revolutionize oncology by tailoring therapies to individual genetic profiles. These implications highlight the need for collaborative efforts in

research, regulatory frameworks, and ethical considerations to accelerate the adoption of personalized medicine in clinical practice.

Keywords: Genetic Engineering, Biotechnology, Personalized Cancer Treatment, CRISPR-Cas9, Genetic Biomarkers, Precision Medicine, Oncology, Next-Generation Sequencing, Targeted Therapy, Ethical Considerations.

1. Introduction to Genetic Engineering and Biotechnology in Cancer Treatment

Cancer is a major health problem in the global context, and by being the leading cause of morbidity and mortality worldwide makes up 9.9 million deaths in 2020. Despite the breakthroughs in understanding the malignancy nature of cancer and strides in medicine research, there has not been any cure for cancer. In a myriad of medical studies to illuminate the possible treatment for this mortal disease, precision medicine represents an effective approach, which enables perfectly customized regimens for treating an ailment. Since the first human-genome project, it has become progressively possible to accurately characterize the genetics responsible for several malignancies and to bring about a remarkable improvement in medical treatment. Harnessing this profound knowledge is a noticeable art in sophisticated clinics which potentially reduce the rusticity of somatic diseases. Major advances have been achieved by unveiling the genetic mysteries of cancer to render an approach more specifically tailored for medical treatment. If these understandings are tapped, the targeted therapy by means of anti-cancerous drugs or immunizations becomes harmoniously functional. This therapy only attacks the altered molecular pathways of the constituent cells/genes of cancer. So, the healthy tissues are being unharmed. It is feasible to identify the concrete mutations which are the face of actinic criteria enhancing the falloff of cancerous cells. In light of a large scope of remarkable success, there are a few challenges in the process of raising a sophisticated strategy for curing cancer. Importantly, a variety of variables like the type or location of particular cancers, the signification of mutations in the development of the cascade of cancer, the time and extent of mutations seems to be categorized as a target and treated, the immunobiological micro-environment and the sensitive/counteractive interactions of the molecular messengers have to be contended with involving a comprehensive strategy considering the whole picture of the person's health. Regarding the aforementioned components, a multidisciplinary teamwork comprising oncologists, bioinformatics, geneticists, genetic cooperators, information technology specialists, pharmacologists, is indispensable towards conducting an efficient therapeutic regimen. Another fundamental point is that the DNA as one of the molecular carriers of cellular information stands for the description of the bounded physical installation of genes, but almost all of the current modeling of genomic experimentations contemplate gene expression and other post-genomic epigenetic configurations. In addition to these considerations, the cellular dynamics and its intercellular communication are missed. [1][2][3][4]

2. Fundamentals of Personalized Cancer Treatment

Cancer continues to represent a major public health challenge worldwide. It is estimated that as many as 1,735,350 individuals will be diagnosed with a cancer and 609,640 individuals die of cancer in the USA in 2018. Of those individuals diagnosed with a cancer, it is estimated that 22.9% will die of the disease within five years of diagnosis. The vast majority of cancer deaths occur because of metastatic spread of the disease. Five-year survival rates for solid cancers in patients whom metastases have developed are considerably less than when the disease remains localized. However, there is considerable optimism that this grim picture will be ultimately

changed because of convergence of a number of novel technologies that will fundamentally change how patients with cancer are diagnosed and treated [5]. As a result of these technical advances there is the realistic possibility that most or even all cancers will become manageable chronic diseases. Remarkable progress in improving survival rates for a number of solid cancers has already been made in recent years.

It is now recognized that cancer is a genetically and phenotypically highly heterogeneous disease. For example, even within a specific cancer type, different patients can have mutations in different genes and these mutations can give rise to different types of tumor cells. Tumor cells can also rapidly evolve once a tumor is established and as a result one tumor is frequently comprised of a collection of sub-clones which are genetically different. In a larger view, this heterogeneity means that the disease that is termed, e.g., colon cancer, in two different patients is likely to be different at a fundamental genetic level. Such heterogeneity greatly complicates the development of potential treatments for the disease. The presence of different driver mutations in different patients is anticipated to necessitate the use of different drugs to achieve the best treatment outcomes. [6][7][8]

3. Genetic Biomarkers and Their Role in Personalized Cancer Treatment

In-depth genetic biomarker identification has only become a possibility over the past two decades. Following the base human genome mapping, the vision of identifying individual genetic traits that could impact treatment efficacy was revisited. The rapid progress of genetic engineering and biotechnology laboratories, and the continuous technological developments that followed suit, enabled exponential growth in the knowledge of the human genome and the identification of genetic traits that could act as biomarkers to determine cancer prognosis and treatment efficacy [9]. Hence, genetic biomarkers represent the first layer of information available regarding genetic patient traits and their treatment implications. Nonetheless, while it has been shown that generic genetic biomarkers can determine general patient populations that may, e.g., respond poorly to a certain compound, personalized cancer treatment methods should also address individual patient genetic biomarkers. Since patient genetic traits are unique, whenever a genetic biomarker is found to be indicative of prognosis as well as of treatment efficacy, it is important to target these specific traits with personalized drugs. Initially, genetic tests could only focus on the isolated examination of a single genetic biomarker. However, the development of the genome wide analysis technologies rapidly increased the number of genetic biomarkers that could be tested simultaneously [10].

While genetic biomarkers are treated as a distinct layer of biomarkers, genetic information can also be used for other levels of biomarkers. For example, genetic tests could be performed to determine the patient's metabolic activities, these input variables could then in turn be fed to pharmacokinetic models to predict the rate of drug absorption and meta. Another example can be the use of genetic tests for the determination of an individual patient's tumor cell kill rate parameter and/or population doubling time. This information could then be used as inputs to establish radiobiological models or advanced data mining methods that can predict the optimal drug to be used with radiation or even determine the benefit of integrating advanced radiation types. [11][12][13]

4. Next-Generation Sequencing Technologies in Cancer Genomics

The recent introduction of next-generation sequencing technologies to cancer genomics has spurred a vast increase in the breadth and depth of discoveries about the somatic alterations that occur in a multitude of tumor types. Large-scale discovery projects have characterized the somatic mutation profiles of a few hundred cases in as many as 10–20 tumor types, in aggregate cataloging many somatic alterations in several thousand different genes. While many of these events are rare or likely 'passenger' phenomena during tumor pathogenesis, a core set of a few hundred cancer genes have been identified that are somatically altered at significant frequency in one or more cancer types. These genes encompass all classes of proteins and include those

encoding well-known drug targets such as the EGFR gene in non-small cell lung adenocarcinoma and the ESR1 gene in breast cancer. They are enriched for kinases, as well as genes involved in cell cycle regulation. There are recognized examples that otherwise rare, somatically altered events can, in specific tumor types, recur and/or contribute to tumor pathogenesis, a group of genes so named as ‘mountain’ drivers. However, the aggregate of these various genes encompasses a wide range of functions and clinically relevant biological processes [14].

At the same time, these endeavors have also revealed a ‘long tail’ of less frequently mutated genes that are collectively altered at 2–6% frequency in many tumor types. Due to the focus on discovery, little is known about the biological pathways or processes most of these genes influence when mutated in a tumor. However, it is logical to assume that at least some fraction of the genes in this mutational spectrum contribute to perturbation of biological pathways relevant to onset or progression of the tumor phenotype. It has been hypothesized that a majority of these genes operate near the end of pathways with known cancer genes, acting as signal amplifiers. In this regard, they function in an oncogene-like manner but are harder to detect due to the many different genes and mechanisms by which they might effect a cancer-relevant phenotype. On occasion, a non-traditional analysis approach might be needed to discover a driver role – for example, considering non-coding or gene break fusion events. [15][16][17]

5. CRISPR-Cas9 Technology and Its Applications in Cancer Research

Cancer is a group of diseases that result in uncontrolled proliferation of cells. It is a major public health problem worldwide and the second leading cause of death in the United States. Personalized cancer treatment involves the adoption of precision medicine, which takes advantage of the genetic and molecular characteristics of tumors to directly target the dependencies of cancer cells. This is beneficial for minimizing systemic toxicity, which can cause adverse effects. Oncology is a rapidly growing field of medical science that aims to diagnose, treat, and prevent tumors. Traditionally, surgery, chemotherapy, and radiotherapy have been widely used as major treatments for cancer. With the advent of biological engineering, gene therapy has shown promise in combating cancer based on the genetic mechanisms of tumors. The rapid development of biotechnology and engineering has produced diverse techniques such as the CRISPR-Cas9 system, TALEN system, and ZFNs [18]. Firstly, the clustered regularly interspaced short palindromic repeats (CRISPR) system is a defense system in microbes that target infectious extracellular nucleic acid and play an essential role in maintaining genomic homeostasis by blocking further pathogen attack. In 1987, the first type of CRISPR system was discovered in Escherichia coli K12, which accelerates the molecular engineering revolution by integrating a nuclease, RNase, and DNAase for a programmable genome. Soon after, researchers repurposed the system to enable RNA-guided targeted genome cleavage. Since then, the CRISPR system has generated enormous interest in academic research and commercial interests. CRISPR has since evolved and expanded to yield a diverse range of technologies. This powerful tool has outperformed other nuclease-based genome editing tools such as ZFNs and TALEN systems due to its high accuracy, efficiency, strong specificity, and ease of design. With the development of the CRISPR system, aberrant genes can be removed, replaced, or modified with a simple protocol. At the same time, it can also be utilized to manipulate cells and model organisms to better understand their role. Given cancer is a multifactorial and hyperplastic disease caused by an excessive accumulation of mutations leading to the activation of oncogenes and the inactivation of tumor suppressor genes, CRISPR/Cas9 is now the therapy of choice for tumor genome editing. Tumor genome editing is broadly classified into two applications. Cancer immunotherapy is the improvement of the host immune system to recognize and eradicate tumor cells by using immunomodulators. Since cancer is widely recognized as an immune suppressing disease, it is no surprise that cancer immune editing can stimulate the elimination-phase immunosurveillance leading to the outgrowth of non-immunogenic tumor cells. In recent decades, biological and cancer research has revolutionized the immunotherapeutic approach of

cancer due to the interplay between the immune system and the tumor. Breakthroughs in this field, which have been demonstrated to be efficient in situ and even broadly effective, are summarized. [1][19][20]

6. Immunotherapy and Biotechnology in Cancer Treatment

The most meaningful advancement in cancer treatment in the last several years has been the start of immune therapy, especially the emergence of the checkpoint inhibitor blockade and adoptive T cell therapy. The remarkable clinical effects of these approaches have been described in a wide range of tumour types, with long-lasting effects in patients with very poor prognosis. Despite these advances, a large fraction of tumours are not responsive to these treatments, and, hence, great effort has been recently given to investigate what is required to ‘‘convert’’ a cancer patient such that they will benefit from immune therapy. This effort can now take advantage of recent technological progress in high-throughput sequencing, as well as computational efforts made to develop suitable algorithms and pipelines. [21] The first part describes some of these advances, the use of different immunotherapy modalities and the basic principles of cancer immunogenomics, followed by a more in-depth discussion on the approach to detection of cancer neoantigens, and how these principles can be used to derive more efficient pipelines for the advancement of a broader clinical effort. In contrast to other oncology and haematology fields, where one can find multiple new therapy perspectives that combine new biological and chemical therapeutics, lung cancer, and non-small-cell lung cancer, in particular, has not achieved success. The first breakthrough in therapy of NSCLC patients was the discovery of actionable mutations in the epidermal growth factor receptor. Other targetable lesions were identified soon after; however, targeted therapies are effective only in patients with certain subsets of lesions. [22] As approximately 50% of lung cancer patients do not have any known driver actionable mutations, biological therapy strategies for this tumour group were pursued using the patient’s immune system. Now, multiple types of immunotherapy can be applied in lung cancer patients, including cancer vaccines, adoptive T cell therapy, genetically engineered T cells, and oncolytic viruses.

7. Nanotechnology in Precision Medicine for Cancer

Introduction Cancer currently causes millions of deaths worldwide each year and continues to rise in prevalence. The burden of this disease is particularly increasing in low- to middle-income countries as a result of aging populations and the increased adoption of cancer-causing behaviors. The development of drug resistance during therapy is a major challenge due to the microevolution and heterogeneity of cancer cells in a tumor. From a tumor perspective, the microenvironment of tumors evolves rapidly, endangering drug distribution and retention in diseased tissues, and adapting rapidly to shifting conditions from treatment. The immune microenvironment of the tumor is characterized by various phenomena that contribute to the persistence of tumors and reduce the effectiveness of therapy. Fortunately, nanomedicine could be taken advantage of as a versatile tool box for addressing quick escape and evolution issues. In terms of biosafety, it is important to have a mechanistic comprehension of the transformation of NPs in biological systems for the traditional gene sequencing technology. Therefore, this review aims to introduce how nanotechnology has inspired new research lines, as well as the challenges and potential solutions for studying the long-term biological fate of NPs [23].

8. Advancements in Gene Editing Techniques for Cancer Therapy

Ever since the first study on gene editing of drosophila genes was done by CRISPR/cas9 in 2013, much has changed. The clinical treatment of gene editing and biological technologies turns from far away to near at hand. In order to meet these wide changes, the discipline of medical genetics also slowly shifts its focus from basic research to clinical practice. The arrival of gene editing therapy strategy shows that the practice of genetic engineering in the medical field goes into a totally new era. This often brings about uncontrollable off-target effects and specific ethical assessment issues in the field, so the widespread use of these technologies in the medical field

would have to tackle these significant debates [24]. Evaluation and concern for these foreseeable issues would also need to be followed by debate and progress in legislation.

When it comes to the clinical practice of genetic diseases, the discipline benefitting the most from gene editing techniques would be medical oncology. As a result of high mutation rate and drug tolerance, cancer often exhibits complex drive-gene mutations as well as transposon element mobility after adaptability to external and derived drug occurrence. Due to its various sources, the mechanisms of cancer are more complex than other genetic diseases which leads to there having few effective drugs and treatment methods in modern medicine world, especially when the cancer progresses into an advanced phase. There are still couple of difficulties facing the small application of clinical tumors currently.

9. Challenges and Ethical Considerations in Personalized Cancer Treatment

Cancer continues to affect a large population without discrimination between sex, ethnicity, religion, or nationality. Cancer, in fact, is a generic name given to a disease having more than 200 different types. Luckily, many of the etiological or causative factors are now being documented accurately, leading to a better understanding of pathways of the disease. Cancer is the disease of genetic regulation controlled by proto-oncogenes, oncogenes, and tumor suppressor genes. And its disease-causing agent is either hereditary or acquired. The well-established treatment strategies of cancer are surgery, chemotherapy, and radiation therapy though they are nonspecific, and normal fast-growing cells of the body are also destroyed. This leads to severe side effects and decreases the quality of life. Treatment strategies of cancer saw a big development along with the completion of the human genome project and the drafting of the human genome sequence. Comparing the normal human genome with the cancer genome appears to be a landmark in establishing personalized cancer treatment. It helps to develop individual targets involving correct genes or proteins. It revolutionizes the treatment of cancer and a new era of personalized treatment starts [25]. As largely the regulatory part of the gene is affected, the protein function is altered. The recently developed treatment strategies of cancer, with the help of the regulation of the formation of a protein product, consist of antibodies, RNA silencing, and small molecules. Harmful cancer-causing fast-growing informative proteins are stopped and further cancer development can be suppressed. Bionic-arm-integrated muscle drive system is a novel design of prosthetic arms that integrates robotic technology and traditional prosthetics to provide the individual with natural control.

Cancer is one of the foremost death-causing diseases, with an increase year to year. Therefore, the standard chemotherapeutic, radiation therapy, and surgical processes are not too effective as they have many side effects. This review focuses on the novel technological development strategies of the treatment of cancer. The most recent development of technological strategies of the treatment of cancer are described below. [26][27][28]

10. Regulatory Frameworks for Genetic Engineering and Biotechnology in Cancer Therapy

Gene therapeutics and cancer biotherapeutics is the development of genetic engineering and biotechnology for the treatment of cancer. Advances in genetic engineering and biotechnology have paved the way for the development of innovative cancer biotherapeutics, such as personalised cell- and genome-based cancer therapies that are tailor-made for individual patients based on their genetic and epigenetic profiles [29]. However, cancer gene therapeutics and biotherapeutics have also demonstrated the ability to accumulate mutations that attenuate their potency or convert them into pro-tumorigenic agents, posing potential threats to biosafety and clinical efficacy. Moreover, there are also great challenges and difficulties for developing cancer gene therapeutics and biotherapeutics, such as drug resistance, heterogeneity of solid tumors, and a hostile tumor microenvironment. Thus, there is an ongoing need for the continual development and improvement of cancer gene therapeutics and biotherapeutics.

Gene therapy is an experimental technique that uses genes to treat or prevent disease. In the future, this technique may allow doctors to treat a disorder by inserting a gene into a patient's cells instead of using drugs or surgery. Research can deliver targeted, safe, and highly effective gene-editing therapy to cancer cells without significant side effects. Toll-like receptor agonists can potently activate human antigen-presenting cells and drive Th1 response. By generating NanoVaxID, a nanoparticulate TLR7/8 agonist stabilised with polyethylene wax and loaded with cancer antigen, the combination of personalised dichlaurin conjugate vaccine and NanoVaxID can safely generate T and B cell responses in the induction phase of clinical vaccination, in particular high avidity CD8+ T-cells.

11. Future Directions and Emerging Technologies in Personalized Cancer Treatment

Cancer is a major cause of death worldwide. Despite significant advances in cancer research and treatment, including the development of immune- or gene therapeutic interventions, many available therapies cannot provide cures and patients still face the likelihood of developing resistance [30]. Developing novel therapeutics is necessary, but unfortunately, the average cost for developing a drug now exceeds over $2.5 Billion USD. The problem is even greater in many countries where the health systems rely on public resources. In this scenario, individuals' access to innovative drugs is much slower and more limited, as decisions on which drugs are made on the basis of "cost-effectiveness" [31]. Cost-effectiveness, in turn, is based mainly on large cohort studies of few patients with similar cancer types, while disregarding the high inter-individual variability in cancer genealogy and related molecular pathways. The utilisation of genealogy for therapeutic optimisation involves the development of sophisticated mathematical models. This is due to the complexity of the regulatory mechanisms in living cells, characterised by numerous genes and metabolic pathways that act on different time scales, and for which only partially validated model is available. So far, the successful applications of models in biology went through significant simplification: linear or mass-action approximations of the rate equations were used; or the experimental setup was greatly limited, not allowing for the proper identification of the parameters of the models. Moreover, the utilisation of models for novel therapeutic strategies is even harder, as it often involves drug design hence specially difficult because of the necessity to consider the geometry of the molecule due to side effects and the involvement of many genes or proteins in the counteracting process.

12. Clinical Trials and Implementation of Personalized Cancer Therapies

The purpose of traditional oncology practices has been to treat patients suffering from cancer tumors on the basis of their tumor site of origin and histological subtype. These treatments are usually the product of long-standing recommendations and do not significantly incorporate the prevalence of individual genetic alterations. Precision oncology refers to the utilization of rapid advances in genomic and other molecular technology to interrogate each tumor's omic and immune profile and identify its unique alterations. This information would then be used to provide a more personalized approach to treatment, mainly by the means of novel drugs and drug combinations. Large-scale trials of cancer genomics have made great strides through efforts such as. Due to the complexity of tumors, they often develop more mutations that may drive resistance to therapy. Genotyping a patient's tumor at initial diagnosis or at progression of disease may suggest a customized approach to therapy for their individual condition. Drug combination is often suggested on the possibility of overcoming these resistance compared to monotherapy, but experimental verification is required. There are however, multiple approaches to the computational or mathematical level, where various methods have been implemented to investigate the drug's dosage, administration, schedule, and so on in order to (re)sensitize the tumor cells to treatment. There are more than two million newly-diagnosed cancer patients in the United States and the patient-to-drug-choice problem is tackled by considering the marker list inferred through comprehensive molecular profiling of individual tumors. For example, an optimal treatment selection model has been developed to maximize the overall survival benefit across the patient population and numerous clinical trials evaluate personalized drug regimens

based on genetic markers. Single cancer tumors, however, consist of multiple genetically different subpopulations and, thus, develop a significant level of intra-tumor heterogeneity, making genotyping even more challenging. This urges the utilization of more complex experiments, current efforts having yielded next-generation drugs that grant a new set of perspectives. Moreover, combinations of drug administration schedule are analyzed computationally for better chemotherapy outcomes. It is expected to witness a synergistic interaction between the two.

Personalized medicine is hoped to impact healthcare significantly. To assist in potential experimental design and yield a better understanding of how various parameters affect the growth's kinetics, a comprehensive studies have arrived at models that are employed to dissect the complex process of solid tumor growth and to analyze in detail how drugs inhibit such an uncontrolled growth. Individual tumors are not homogeneous structures, but rather mixture of genetically different subpopulations, thus giving rise to intra-tumor heterogeneity development. Due to the complexity of such systems, these are compared with concepts from population genetics. Tumor growth is studied as the population's expansion with the goal of eventually taking over the organ. The size distribution of the most fit mutations is shown to follow a power-law that changes abruptly to a flat distribution in association with the onset of the large-scale expansion. Furthermore, it is proposed a simple model where this population is driven by the fastest growing subpopulations. The knowledge of the relevant parameters characterizing birth and death rates can be employed, given the drug mechanism of action, to design treatment schedules that most effectively reduce the total population. [32][33][8]

13. Case Studies and Success Stories in Personalized Cancer Treatment

One of the first achievements of the cancer genome project was the identification of resistance-conferring mutations in the epidermal growth factor receptor (EGFR) kinase domain of tumors of patients treated with the EGFR inhibitor gefitinib [34]. These mutations decommission the targeted drug. In principle, the sequence of the cancer genome of a patient could be interrogated, resistance mutations to many candidate targeted drugs could be predicted in such manner, and essential predictive resistance mutations (EPRMs) not already present in the cultivable subclones of the cancer would indicate an improbably resistance-free combination therapy among the investigated drugs. Although theoretically straightforward, this is thus far not clinically useful due to the cost-prohibitive necessity of prior long-term cultivation and genomic sequencing of multiple clones derived from a single invasive biopsy. The rapid expansion of the molecular profiles accessible in fixed, paraffin-embedded tumors has opened the way to a 'personalized oncology' approach to the development of innovative, targeted cancer therapies. Different molecular events might be potentially targeted at the same time, either concurrently or sequentially, to counteract or limit drug resistance. On the other hand, parallel inhibition of redundant pathways to block escape mechanisms might be a winning strategy in the treatment of molecularly targeted therapies. Combination treatment has been shown feasible and of potential clinical impact in diseases of hematologic origin. However, translating findings in leukemia biology into solid tumors has often been tricky and not straightforward.

14. Collaborative Efforts in Cancer Research and Treatment

For the third year in a row, researchers in the US published a record number of cancer-related data. Although this outpour of data is not yet being matched by similar growth in knowledge that would accelerate medical progress, scientists in the lab and clinic are in the midst of a transformational time in cancer research and treatment. There is a growing body of proof that indicates cancer can be both deficient in immunogenicity and immunosuppressive. However, treatments that focus on manipulating the immune system to specifically kill tumors are displaying very encouraging results. Recent work has focused on the development of more accurate tumor models and harnessing the specificity of the immune system to develop effective cancer vaccines or mAbs [5]. Currently, of the approximately 250 drugs that have been approved

for cancer treatment, less than half are selective for cancer cells. However, this number is expected to grow as novel and innovative drug mechanisms of action are being utilized in clinical trials. Three recently licensed small molecule drugs inhibit the V600E mutation acting RAF kinase –a critical component of the MAP kinase cytostatic driver cascade harboured by approximately 60% of cases of melanomas. Irrespective of existing or novel targeted drug combinations, the personalized treatment approach has resulted in improved patient outcomes in Phase I clinical trials that selected patients using a specific biomarker. Drugs targeting the PI lipase A/AKT/mTOR signaling axis have shown a 51% disease control rate while matched treatment is only detected in 9% of unselected patients. Similarly, matched antiestrogenic treatments resulted in an 18% response rate while only 3% of unselected patients responded.

15. Economic Implications of Personalized Cancer Treatment

The developing breakthroughs in personalized cancer treatment, through the innovation of new drugs and reliance on biotechnology, gene editing, and CRISPR now pave the way toward possibly better patient outcomes. Programmed precision therapy (PPT) would utilize the information gleaned from patient genomes to tailor treatments to the physiological systems which auto-regulate patient health. This perspective attempts to investigate current advances in DNA sequencing technology and CRISPR gene editing, and the versatility of biological medicines in treating more apparently complex symptom-related diseases like cancer. It is important to discuss these curiosities and parameters which will shape the ethical implications of potential changes to healthcare treatment. By understanding them, we can better govern and distribute the benefits that rapidly advancing biotechnologies could offer in the near future [5]. This also includes the adoption of more stringent regulations on both biotechnologies and the data security firms which will have access to these revolutionary therapies. This also proposes the ethical considerations and economic implications which could encourage the acceleration or inhibit the development of PPT.

Economic Implications of Personalized Cancer Treatment (PPM): In the past few years there have been great leaps in the fields of biotechnology and gene editing, particularly in oncology research. Insight into the molecular pathways of tumours has led to a deeper understanding of cancer biology as well as the identification of high specificity drugs. Though statistics show that cancer trends are still rising, cancer patients are on average living longer now than they were a decade ago. Augmenting this research, a rapidly expanding field of biotechnology has emerged, causing a hype among healthcare professionals about the future of treating any complex symptoms-related illnesses.

16. Patient Advocacy and Empowerment in the Era of Precision Medicine

As a patient advocate, you work tirelessly to make the journey of those going through the most difficult time of their lives a little easier. This can manifest in advocating for healthcare reform on behalf of patients in support groups, arranging to have the bills of an in-need family paid for by a generous benefactor, making sure those who are often forgotten have their needs met, fundraising for cancer research on behalf of a family member who recently died of the disease, or being the rock that the patient leans on when all else crumbles. These and countless more acts just like them are the ways you make a significant difference in the day-to-day life of those that are afflicted by cancer by ensuring they not only have a voice but that it is heard and likely effecting change. As the era of precision and PPM continues to grow, so too must you by arming yourself with the knowledge necessary to help guide those for whom you advocate in our rapidly changing world. Behind the advancements made by PPM are innovative IVDs that make the leaps and bounds of treatments possible by identifying predictive biomarkers and by elucidating patient health from a singular genotypic perspective. Skepticism can surround new advances, particularly informatics in a hospital setting, as without a standard system or computer scientists on their team, hospitals struggle to handle the influx of data and interpret it properly. When viable therapeutic changes came from these PPM advances, physicians still have great hurdles to

leap such as being overly cautious in determining the validity of PPM information, understanding the data despite not having grasped complex statistical methods in their education, and figuring out what the data means and how they accurately interpret data to effect a therapeutic change while keeping healthcare costs down. All of these components must be properly in place and understood to ensure the continuing advancement of the PPM field, and as a patient advocate, it is imperative that you are aware of each, as it may largely fall to you to educate and help guide patients when the doctor simply does not have the time. [35][36]

17. Education and Training in Genetic Engineering for Cancer Therapies

Cancers are heterogeneous group of diseases that arise from genetic alterations in the normal cells that affect multiple cellular pathways and functions. The possibilities of adaptation and evolution of cancers under variations of selection pressures render them hardly curable through an ordinary monotherapy. Harnessing both strengths and limits of contemporary genetic and biotechnological achievements, there has been remarkable effort from academia, industry, clinicians, and governments to develop innovative genetic engineered anticancer tools and applications facilitating the specific detections and targeted killings of the tumor cells with minimal side effects [37]. The accumulative findings have revealed that the alterations can be roughly categorized into susceptibility, diagnostic, prognostic, and therapeutic genes. These genes confer inherit risk of malignancy to an individual and/or provide the tumor cells with growth advantages or metastatic potentials. The success of genome-wild association and large-scale sequencing studies in the detection of tumor susceptibility genes raises the possibility of cancers prevention by gene surgery, therapy intensification guided by individualized genetic testing, or cancer prevention by gene surgery, therapy intensification guided by individualized genetic testing. Nonetheless, issues on the righteousness and effectiveness of gene disclosure and manipulation, and the practicality of these laboratory bench concept on clinical bed still make the development and implementation of these revolutionary approaches full of challenges [38]. As rapid advance of comprehensive and deep-going biology methodologies and as large of multidisciplinary and multi-institutional efforts on cancer genome projects, genetics and biology of cancers have now entered the era equipped with powerful and detailed information. On the platform of genomic sequencing and gene expression profiling, landscapes of human genetic variations, cancer vulnerable genes in DNA levels, cancer associated pathways and gene expressions have been largely delineated. Moving beyond the traditional constraints of cytotoxicity and cytostaticity, modern cancer therapy can make use of a large variety if anticancer drugs with well-elucidated or still-enigmatic mechanisms. Further, in the face of high mortality and severe sufferings caused by invasiveness and drug resistance of malignant lesions, traditional means have long been the front weapon to fight against cancers by surgeons, radiotherapists and medical oncologists.

18. Global Initiatives and Partnerships in Advancing Personalized Cancer Treatment

Patient demographics have shown a significant skew to low- and middle-income countries where capability for treating cancer is often lacking. In response, there has been a concerted effort by global health bodies, governments and pharmaceutical manufacturers to improve availability of anti-cancer drugs. Stringent patent laws can make these drugs unavailable or unaffordable in some regions and so from 2003 to 2017 the World Health Organisation’s Commission on Intellectual Property Rights, Innovation and Public Health have undertaken to increase legal access for such countries to cheaper generics. The aim is to encourage generic manufacturers to supply the drugs. Campaigns of negotiation have been based on development of expertise in treatment costs relevant to a patient’s co-morbidities, diagnosis and prognosis [34]. Focus on the individual is important, since cancer has now been recognised as many diseases with the same symptoms, and therapy must exploit multiple channels to avoid resistance and achieve long-term efficacy. Efforts have been targeted at four cancers - breast, liver, lung and cervical [5]. In addition to this, have coordinated a number of initiatives in a cancer research partnership, dedicating funding to multidisciplinary research programs. In response to the development of

successful drugs companies are designing trials specific to patients' genetic anomalies with the aim of developing a companion diagnostic tool. In parallel with this, orphan oncogenes are being screened to develop 'Global Trike' drugs that can treat many cancer types. Finally, a phase exhibition program was launched in 2015, five years before the average approval time.

19. The Role of Artificial Intelligence in Personalized Cancer Therapy

The promise of personalized cancer treatment lies in the realization of patient-individualized therapy strategies. The synoptic implementation of State-of-the-Art techniques is critical for extensive and precise prediction of the therapeutic advantage of cancer therapy. The promise of personalized cancer medicine is expected to be realized through the implementation of innovative genomic, epigenomic, proteomic, transcriptomic, and dosimetric assessment technologies. Artificial intelligence is recognized as an outstanding tool for the integration and analysis of the extensive data files generated on these omics projects. General, the ever-growing work has a significant influence on innovated applications relative to safety and efficacy outcomes. With the help of an individualized optimization of cancer radiotherapy, the prospective primary goal of this clinical trial was to try and design a study direction to evaluate if an assistant founded on published community-based preclinical investigations would be useful. The percentages of correctly-split predictions surpassed 50 % for the two most common p53 genetic mutations, enriching the possibility of translating these findings into patient treatment [29].

20. Societal Impact and Public Perception of Genetic Engineering in Cancer Treatment

Genetic engineering and the biotechnological methods that have come with it have profoundly impacted the fields of biology and medicine. Notably, in relation to cancer, they have developed methods that have revolutionized the way malignancies are diagnosed, as well as created drugs that have improved patient outcomes while often reducing side-effects compared to chemotherapy and radiation. Despite all of these benefits, the expansion and development of biotechnologies has given a platform for concern to many, including whether society is prepared for their emergence and what consequences these technologies will have on the world at large. In the discussions of genetic engineering, the primary focus has been on its applications in the treatment of cancer and the impact it has had, but also what challenges are yet to be addressed and how society has reacted. [39][40]

21. Conclusion

Meta-analyses have also aimed to identify driver mutations and other risk factors for CRC. Some commonalities have been found in different CRC subtypes such as the presence of CTNNB1 and KRAS mutations, which are not found in normal colonic cells. CRC seen in younger patients tends to have a higher frequency of BRAF mutations, a high CpG island methylator phenotype, and less chromosomal instability as compared to CRC seen in older patients. All three of these molecular features seem to correlate with MSI. In particular, the presence of a BRAF mutation in right-sided CRC provides a very positive prognostic outlook in terms of overall survival as compared to the presence of a KRAS mutation, or wild-type tumors. Knowledge of molecular subtypes of CRC is clinically important for ensuring the best possible treatment outcomes are achieved for a patient. In particular, patients with the greatest number of alterations appear to benefit the most from systemic therapy. Future work must continue to seek further corroborative data for the molecular and subtyping features of CRC so as to better individualize treatment strategies. In the age of fast-evolving medical technology treatment is rapidly moving away from a one-size-fits-all approach towards precision and personalized medicine (PPM). This new approach is not limited to cancer treatment, but as cancer mutations are well studied, this approach is particularly relevant. Although drugs directed only at specific mutations can be effective, such therapy often has a limited window of effectiveness, as other alterations that drive tumor growth often quickly arise. In recent years there has been a growing trend towards the development of other tools for PPM enaction, such as the treatment of cancers with vaccines or

monoclonal antibodies. Efforts in this space have included research that has focused on the development of more accurate tumor models, and research that aims to harness the specificity of the immune system to develop effective cancer vaccines or monoclonal antibodies. A stratified, personalized treatment approach has been shown to be immensely beneficial, typically resulting in drastically improved patient outcomes in terms of response rate and progression-free survival in Phase 1 clinical trials relative to those that did not use a specific biomarker for patient selection. These statistics are striking, and show a dramatic improvement in patient response when they are matched to treatments for their specific disease.

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