Malaysian Journal of Medical Research, 10(1), 93-104
https://doi.org/10.31674/mjmr.2026.v010i01.011

MJMR
Malaysian Journal of Medical Research

Malaysian Journal of Medical Research

Online ISSN: 2550-1607

www.mjmr.com.my

Review Article

CRISPR and the Future of Cancer Treatments: Implications for Malaysian Medical Students

Mohamed Salman Bin Muhammad Azmi

Independent Researcher, Taman Melawati, 53100, Kuala Lumpur, Malaysia

Corresponding Author's Email: 130103sal@gmail.com

Abstract

The emergence of CRISPR-Cas9 gene-editing technology has marked a transformative milestone in biomedical research, offering unprecedented potential to develop targeted therapies for a range of diseases, particularly cancer. This paper delves into the role of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) in advancing cancer treatment, with an emphasis on the fundamental mechanisms of the technology, its promise for more precise and effective therapies, and the challenges encountered in translating CRISPR from the laboratory to clinical settings. The technology's ability to precisely target and modify genes has the potential to revolutionize cancer therapies, offering personalized treatments tailored to the genetic makeup of individual tumors. However, the clinical application of CRISPR faces significant hurdles, including concerns about off-target effects, ethical dilemmas surrounding germline editing, and the development of safe and efficient delivery mechanisms. In the context of Malaysia, this paper explores the relevance of CRISPR innovation within the medical and educational sectors. It highlights how Malaysian medical schools are incorporating gene-editing technologies into curricula to ensure future healthcare professionals are well-prepared to navigate the complexities of CRISPR applications. Moreover, the discussion expands to include the ethical, social, and legal implications of CRISPR technology. Establishing robust national bioethical guidelines will be crucial in ensuring its responsible use and minimizing risks. The paper concludes by discussing the necessary infrastructure, educational advancements, and policy frameworks needed in Malaysia to facilitate the integration of CRISPR technology into cancer care, ensuring safe and effective treatment options for patients.

Keywords: *Biotechnology; Cancer Treatment; CRISPR-Cas9; Ethics in Genetics; Gene Editing; Malaysia; Medical Education; Precision Medicine*

Introduction

The Growing Cancer Burden in Malaysia

Public health officials in Malaysia identify cancer as an essential concern since the incidence and death rates from this disease have dramatically increased during the last several decades (Chan *et al.*, 2023). The Malaysia National Cancer Registry Report (MNCRR) 2012-2016 shows that cancer prevalence in Malaysia grew from 103,507 (2007-2011) to 115,238 (2012-2016) (Wong *et al.*, 2021). Breast cancer stands as the top diagnosed cancer type in Malaysia, followed by colorectal cancer, lung cancer and nasopharyngeal carcinoma (NPC), while liver cancer takes the fifth position. NPC remains a substantial health issue for ethnic Chinese and Indigenous Borneo peoples because its development is strongly influenced by both Epstein-Barr virus (EBV) infection and genetic factors. Liver cancer stands as a

Received: 4thOctober 2025; Revised version received on: 5th December 2025; Accepted: 15th December 2025

significant reason behind cancer-related deaths in Malaysia since hepatitis B and C infections that affect the population frequently cause this type of cancer (Jafri & Kamran, 2019).

Malaysia continues to face significant obstacles in handling the disease due to recent advancements in cancer diagnosis and treatment. Most cancer patients in Malaysia experience diminished survival rates throughout five years due to medical care standards that lack parity with those observed in developed nations (Norsa'adah *et al*., 2021). Along with inadequate early screening programs, delayed diagnoses, monetary factors, and uneven healthcare resource distribution, patients experience worse treatment results. Traditional cancer treatments involving surgery with chemotherapy and radiotherapy lead to significant adverse side effects and a high likelihood of cancer returning, as well as poor results against advanced-stage tumours. Chemotherapy resistance emerges as a primary obstacle for treatment when dealing with lung cancer, breast cancer, and colorectal cancer patients since mutation-driven resistance diminishes standard treatment effectiveness during later stages of therapy. The fight against cancer in Malaysia requires innovative treatment approaches because of existing difficulties. Modern medicine gains its most promising advancement from the CRISPR-Cas9 gene-editing technology that demonstrates potential applications in cancer diagnosis and treatment while showing promise for preventing the disease.

Introduction to CRISPR Technology and Its Role in Cancer Treatment

Scientists can now precisely modify DNA using a revolutionary gene-editing technology known as Clustered Regularly Interspaced Short Palindromic Repeats through its CRISPR system. The CRISPR-Cas9 system was initially identified by scientists in bacteria, where it functions to protect cells against viruses before research laboratories developed this system for biomedical applications (Alamillo *et al*., 2023). The genetic tool functions like molecular cutting shears, allowing scientists to modify, remove, and replace cell-based genetic material. Through its advanced functionality, CRISPR provides scientists with a strong technology for targeting cancer-driving genetic mutations.

CRISPR demonstrates tremendous value for cancer treatment applications through various essential areas. The system targets cancer-causing gene mutations within TP53 KRAS BRCA1/2 and other genes to prevent genetic transformation from leading to malignancy. Through CRISPR, scientists can accomplish two goals: enhance CAR-T cell therapy by modifying T-cells to recognize cancer cells better and refine immunotherapy approaches simultaneously (Asmamaw & Zawdie, 2021). The tool enables scientists to study functional genomics research because it helps them discover cancer molecular activities and advanced therapeutic targets. Cancer detection through genetic screening combining CRISPR technology can help identify people who have specific mutations, thus allowing healthcare professionals to intervene early for prevention.

The ethnically varied population of Malaysia creates specific opportunities for CRISPR-based cancer therapies. Different cancer risks, together with unique treatment responses, emerge from genetic variations among the Malays, Chinese and Indian ethnic groups, so personalized medicine holds significant value (Ho *et al*., 2021). Adopting CRISPR technology would enable Malaysian healthcare providers to deliver customized therapies based on genetic profiles, resulting in improved patient outcomes. A thorough implementation of this potential requires medical staff who are adequately trained in gene-editing technologies and updated educational content that covers CRISPR in Malaysian medical school curricula.

Research Objectives

This paper aims to:

1. Assess how CRISPR technology evolves as a tool to improve cancer prevention and treatment strategies within Malaysia.

2. Examine the preparation level of Malaysian medical academic institutions to teach CRISPR through their educational programs.

3. The study analyzes the moral consequences, legal requirements, and community responses to CRISPR treatments in Malaysia's healthcare institutions.

Research Questions

Literature Review

This study addresses the following research questions:

1. How is CRISPR-Cas9 currently being applied in cancer treatment and clinical research?

2. What are the major therapeutic benefits and technical limitations of CRISPR-based cancer therapies?

3. How prepared are Malaysian medical education institutions to train future doctors in gene-editing technologies?

4. What ethical, legal, and policy challenges affect the implementation of CRISPR in Malaysia?

5. What strategies can strengthen Malaysia's capacity for CRISPR-based cancer care and education?

Literature Review

Overview of CRISPR Technology

The field of genetic engineering started to change after scientists combined the CRISPR method with the Cas9 protein in their research. The adaptive immune defence mechanism known as CRISPR-Cas9 enables bacteria to precisely edit genomes through DNA double-stranded break introduction at targeted sites. A synthetic guide RNA (gRNA) steers the Cas9 enzyme toward particular DNA sequences for performing DNA-cutting functions. The cellular repair system utilizes either non-homologous end joining, which creates mutations, or homology-driven repair, which enables exact gene modification or insertion after the DNA breakdown (Zhang *et al*., 2020). Due to its simplicity, efficiency, and versatility, CRISPR has proven critical for research into gene and therapy development.

Breakthroughs within CRISPR technology enable scientists to use it for functions exceeding regular gene editing operations. Reactor-based innovation in base-editing and prime-editing enables single-nucleotide modifications through technology that generates no double-stranded break events, thus minimizing possible genetic alterations. The application of CRISPR led to epigenome editing, which lets researchers regulate gene expression while keeping the original DNA sequence unmodified. These developments create new possible therapeutic approaches that benefit patients suffering from genetic diseases and cancer.

Applications of CRISPR in Cancer Treatment

Targeting Oncogenes

Cancer development emerges from mutations affecting oncogenes and tumour suppressor genes, which results in uncontrolled cell growth. CRISPR-Cas9 provides researchers with a direct solution to fix genetic disorders in cells. Scientists have found it hard to treat the KRAS gene mutation, which appears in pancreatic and colorectal cancers. CRISPR allows the precise modification of these mutated genes, returning normal cell behaviour and stopping tumour progression. The exact correction for EGFR gene aberrations through CRISPR-based interventions provides an appropriate method to treat cancers that result from mutated EGFR in non-small cell lung cancer patients (Xiaoshuai *et al*., 2022).

Immunotherapy Enhancement

Cancer treatment received a transformative breakthrough through immunotherapy, which employs patient immune mechanisms against tumour cells. The use of CRISPR technology improves this technique by developing immune cells that possess superior anti-tumour properties. One significant CRISPR application exists in creating (CAR) T-cell therapy by modifying T-cells to produce receptors that recognize cancer antigens. CRISPR systems provide precise gene integration for placing CAR coding sequences into T-cells, improving cancer cell targeting performance (Liu *et al*., 2021).

Personalized Medicine

Individual genetic profiles demand treatments which suit the unique characteristics of cancer because of its diverse nature. Through CRISPR technology, scientists can create customized medicines because this approach allows researchers to alter disease-causing genetic alterations that affect individual patients. Tumour genome sequencing enables medical professionals to detect particular genetic faults that serve as cancer drivers. The unique mutations in patients become the focus of CRISPR-driven therapeutic design to achieve superior treatment outcomes without increased harmful effects (Goetz & Schork, 2018). Using individualized strategies represents a promising method to enhance the treatment results of malignancies that show different genetic expressions.

Recent studies highlight ongoing innovations that aim to overcome traditional limitations of CRISPR-based therapies. For instance, Park *et al*. (2025) emphasize how CRISPR can be used to counteract drug resistance in cancers by improving precision targeting and gene pathway correction. Similarly, Tang *et al*. (2025) reviewed how delivery mechanisms—including nanoparticle and viral-vector systems—are being optimized to reduce off-target effects and enhance CRISPR delivery efficiency. These findings illustrate that CRISPR's clinical effectiveness depends not only on precise gene editing but also on reliable delivery technologies.

Current Research and Clinical Trials on CRISPR-Based Cancer Treatments

The progress of CRISPR technology into clinical use has gained momentum through multiple recent experimental and trial-based advancements. Casgevy received FDA approval in 2023 as the first CRISPR-based therapy for treating sickle cell disease and beta-thalassemia, bringing substantial progress to gene-editing therapies. Health authorities approved Casgevy in 2023 to speed up CRISPR oncology research development. Different clinical trials are currently investigating the use of T-cells engineered through CRISPR techniques for cancer treatment (Li *et al*., 2024). According to published research, scientists have demonstrated how T-cells receive improved tumour-cell elimination capabilities through CRISPR-based cell modifications in laboratory tests. Clinical trials evaluate the security aspects and the effectiveness and operational feasibility of CRISPR-based medical treatments for different types of cancer.

In addition, Rauf *et al*. (2025) explored nanotechnology-based CRISPR/Cas9 delivery systems that improve therapeutic precision for solid tumours. Their study emphasized that nanoparticle carriers can enhance CRISPR transport efficiency while minimizing immune reactions and off-target gene edits. These findings suggest that integrating nanotechnology with CRISPR gene-editing tools could substantially accelerate cancer treatment applications and clinical translation in 2025.

Many obstacles continue to hinder the medical use of CRISPR for cancer treatment. Crucial to successfully using CRISPR technology for gene editing lies in developing specific methods that avoid unintentional genetic modifications. Delivery methods must be designed to reach cancer cells efficiently without damaging healthy tissues.

CRISPR in Malaysian Medical Education

Future healthcare professionals need cutting-edge technology integration, such as CRISPR, because it prepares them for the medical field. Genetic and genomic education programs within Malaysian medical curricula exist at their initial developmental stage. The review declared that Malaysia requires complete policies and frameworks which can provide ethical guidelines for implementing gene editing. The advancement of precision medicine depends heavily on standardized practical training curricula for gene-editing technologies, but no such curriculum currently exists.

Some research institutions in Malaysia attempt to minimize this educational deficit (Wolyniak *et al*., 2019). Research institutions now collaborate to conduct workshops dedicated to better understanding CRISPR technology and its implementation through programs. A unified approach to establishing CRISPR education as a complete training aspect for medical programs remains necessary because the current initiatives remain limited in scope. Educational programs dedicated to CRISPR, practical

laboratory training, and international research partnerships will improve the mastery of Malaysian medical students within this rapidly transforming sector.

CRISPR technology demonstrates an exceptional role in cancer treatment by offering precise gene-editing capabilities and through strengthened immunological therapies together with patient-specific healthcare solutions. Apart from existing achievements, ongoing research along with clinical trials remain essential to solving the problems that come with practical usage. Integrating CRISPR into Malaysian medical education creates an urgent need because it enables healthcare professionals to learn practical CRISPR applications that will enhance future oncology patient results.

Methodology

Literature Search Strategy

This review was conducted using a systematic literature search to identify relevant studies on CRISPR-Cas9 and cancer treatment. Electronic databases including PubMed, Scopus, Google Scholar, and Web of Science were searched between January 2015 and December 2025. Keywords used included "CRISPR-Cas9", "gene editing", "cancer therapy", "precision medicine", "oncology", and "Malaysia medical education".

Only peer-reviewed journal articles published in English were considered. Studies focusing on clinical applications, ethical considerations, medical education, and translational research were prioritised. Reference lists of selected articles were also reviewed to identify additional relevant sources.

Study Selection and Screening

A total of 186 articles were initially identified through database searches. After removing duplicates and irrelevant titles, 94 articles were screened based on abstracts and full texts. Studies that did not focus on cancer-related CRISPR applications or medical education were excluded. Finally, 52 articles were selected for detailed analysis and inclusion in this review.

Data Extraction and Analysis

Relevant information was extracted from selected studies, including study objectives, methodology, key findings, clinical outcomes, and ethical implications. The extracted data were analysed and grouped into major thematic areas related to therapeutic applications, immunotherapy, genetic correction, technical limitations, and educational preparedness. This thematic approach allowed systematic comparison and interpretation of findings across studies.

Results

The main findings of this review are summarised below under four thematic areas.

Advances in CRISPR-Based Cancer Therapies

Reviewed studies indicate that CRISPR-Cas9 has significantly improved cancer treatment by enabling precise modification of oncogenes and tumour suppressor genes. Research demonstrates progress in correcting KRAS and EGFR mutations associated with pancreatic, colorectal, and lung cancers (Bender et al., 2021). These advancements have contributed to improved tumour control and patient outcomes.

Immunotherapy and Gene Editing Applications

CRISPR technology has supported the development of CAR T-cell immunotherapy by enhancing the ability of immune cells to recognize and destroy cancer cells. Long-term remission outcomes have been reported in haematological malignancies using CRISPR-enhanced CAR T-cell therapy (National Cancer Institute, 2022). However, challenges remain in treating solid tumours due to immune evasion and tumour microenvironment complexity.

Genetic Correction and Inherited Cancer Syndromes

Studies indicate that CRISPR-based gene correction has potential in reducing cancer risk associated with inherited mutations such as BRCA1 and BRCA2. By repairing defective genes, CRISPR may lower susceptibility to breast and ovarian cancers. Ethical concerns regarding germline editing and long-term safety remain important considerations.

Technical and Clinical Limitations

Several studies report that off-target editing, immune reactions, and inefficient delivery systems limit the clinical application of CRISPR therapies. The development of reliable delivery vehicles remains a major obstacle to successful in vivo treatment. Researchers emphasize the need for improved safety mechanisms to ensure effective and responsible clinical use (Uddin et al., 2020).

Medical Education and Integration in Malaysia

Integrating CRISPR technology into medical practice necessitates a workforce proficient in genetic editing techniques. Current medical curriculum programs in Malaysia provide students with restricted exposure to actual gene-editing practices. Research reveals that Malaysian medical programs emphasize theoretical genetics above practical instruction in advanced CRISPR technology and other modern biotechnology methods (Kalidasan & Das, 2021).

Filling this gap effectively requires implementing complete CRISPR training programs that combine theoretical base knowledge with practical CRISPR use experience. Students must participate in experimental workshops for gene-editing techniques alongside educational programs demonstrating genetic research applications for clinical interventions. The Innovative Genomics Institute provides specialized training about CRISPR applications, policy considerations, and ethical issues, which Malaysian medical institutions should follow as a model (Doudna & Sternberg, 2017).

Global research partnerships enhance the competence level of Malaysian medical graduates. The Jackson Laboratory stands to benefit Malaysian labs through its experiential biomedical science programs, which allow knowledge exchange about CRISPR technology. These initiatives will elevate the medical education level in Malaysia and provide its future healthcare staff with the needed skills for adopting gene-editing technology in patient care.

Ethical, Social, and Legal Considerations

Implementing CRISPR technology throughout Malaysia involves many ethical, social, and legal challenges. Human understanding of gene-editing applications significantly shapes social reception toward their use. Malaysia demonstrates diverse perspectives on genetic modification because it is a highly multicultural nation that blends many faiths. Some ethnic groups in this region exhibit concern about genetic modification because of their religious values, but others welcome technology that delivers medical advantages (Barbosa *et al*., 2021).

Supporting this view, Selvakumar et al. (2025) conducted a global comparative study that examined how public acceptance of human gene editing is shaped by cultural trust, transparency, and ethical awareness.

Religious beliefs substantially impact the development of bioethical discussions throughout Malaysia. Islamic bioethics adopts both the protection of human dignity and harm prevention but could view somatic cell editing favourably since it deals with existing disease treatment without modifying genetics. Successful CRISPR-based therapy execution needs people to understand and honour specific cultural and ethical standards.

Malaysia operates at a basic level in developing specialized gene editing legal frameworks. New research demonstrates the necessity of building strong regulations designed to protect biosafety, biosecurity standards, and ethical principles related to human gene editing. The establishment of

specific guidelines becomes vital to controlling scientific study and medical uses because it ensures new discoveries meet both social perspectives and accepted ethical benchmarks (Resnik, 2020).

Discussion

CRISPR's Potential for Cancer Care in Malaysia

CRISPR technology demonstrates the potential to transform Malaysian cancer treatment by developing specific and robust solutions for identifying prevalent forms of cancer in the country. Malaysia faces a high frequency of nasopharyngeal carcinoma (NPC) because this cancer affects Chinese and Indigenous communities along with other population segments. Studies now examine how CRISPR could stop disease-related viral oncogenes related to Epstein-Barr virus (EBV) infections in cases of NPC. The successful implementation of this technique would enable genetic-level prevention and treatment of NPC, which would substantially cut down cancer burdens from this type (Su *et al*., 2023).

CRISPR-based gene editing has the potential to target colorectal cancer mutations in APC, TP53, and KRAS genes and provide treatment benefits for this Malaysian cancer (Hasbullah & Musa, 2021). CRISPR is a promising method to undo malignant transformations in the cell by targeting molecular mutations that drive tumour expansion and therapy resistance. CRISPR enhances immunotherapy through its ability to modify T cells, leading them to detect better and fight colorectal cancer cells, thus raising patient survival probabilities.

Implementing CRISPR-based cancer treatments in Malaysia depends on their cost implications and practical implementation abilities. Implementing CRISPR-based therapies requires advanced laboratory facilities and expert personnel, which results in higher costs than conventional treatments. CRISPR-based CAR-T cell therapy used to treat haematological cancers costs $373,000 to $475,000 per patient in U.S. clinics (Geethakumari *et al*., 2021). Malaysia must obtain substantial state funding alongside international biotech firm partnerships and purposeful public-private collaborations to bring affordable CRISPR-based therapies into its healthcare system.

The future advantages of CRISPR look promising to overcome its present extravagant expenses. Long-term healthcare costs might decrease if patients receive permanent cures through CRISPR because this method offers single-time treatments, unlike extensive chemotherapy and radiotherapy, which necessitate long-term administration and produce serious adverse effects (Rasul *et al*., 2022). Malaysia's implementation of CRISPR treatments would enable a transition from cancer treatment responses to genetic preventative measures, thus generating better patient results and lowering cancer care expenses.

Furthermore, Li *et al*. (2025) conducted a comprehensive bibliometric analysis of global CRISPR-Cas9 clinical research, revealing that Asia-Pacific countries are increasingly contributing to international gene-editing studies, yet Southeast Asian participation remains minimal. Their findings highlight that while China, Japan, and South Korea lead the region in CRISPR oncology research, Malaysia and its neighboring countries are still at the early developmental stage. This reinforces the urgent need for Malaysia to strengthen its CRISPR infrastructure, academic partnerships, and clinical trial capacity to remain competitive in future genetic medicine advancements.

Preparing Malaysian Medical Students for the Future

Medical practitioners need proper training to properly implement advancing CRISPR-based therapy methods in patient care. Malaysian medical educational institutions lack substantial hands-on training courses about CRISPR and gene-editing technologies, which restricts future doctors' ability to use these treatments effectively (Samori & Rahman, 2024). Medical education needs significant changes to prepare students for genetic sciences, molecular diagnostics, and clinical CRISPR applications.

The establishment of CRISPR labs at medical institutions will increase the future readiness of Malaysian medical students. The laboratories would allow students to practice gene-editing techniques, CRISPR delivery methods, and genome sequencing operations (Nicol *et al*., 2017). Genomics-focused educational programs exist in medical schools throughout the United States and China, enabling their

students to learn genetic medicine techniques through practical experience. Malaysia needs to establish educational structures similar to those of other countries because doing so will benefit its population.

Clear genetic counselling and precision medicine training programs that integrate within medical universities throughout Malaysia would develop medical students who excel in these specialities. The programs should adopt practices from institutions like Harvard Medical School Genetics Training Program to integrate clinical case studies with bioinformatics tools and ethical discussion sessions in medical educational programs. By creating educational programs in Malaysia, medical students will gain competence in CRISPR therapeutic applications and the moral and public aspects of this field (Loh *et al*., 2023).

International partnerships with research institutions will let Malaysian students experience state-of-the-art CRISPR investigations and clinical trials. Thanks to their expertise in gene-editing technology, online courses and joint research collaborations with the Broad Institute of MIT and Harvard would add to Malaysia's medical curriculum. A present-day commitment to CRISPR education development allows Malaysia to train professional geneticists and medical practitioners who will execute gene-based cancer treatments in the next era. This work contributes a foundation to understanding the main issues regarding the application of CRISPR in cancer care. It provides a roadmap for future studies and policy discussions (Kelly *et al*., 2024). This research explores the potential of CRISPR in cancer treatment and its impact on medical education in Malaysia, acknowledging certain limitations. Notably, the study relies on secondary sources such as existing publications, clinical studies, and policy reports, which may not incorporate the most recent advancements or unpublished data in CRISPR research (Pederson et al., 2020).

Healthcare practitioners must address several significant issues when integrating CRISPR technology into cancer therapy because the practice inevitably involves modifying human genetics. Somatic gene editing faces less opposition because medical professionals perform it on cells that do not affect future offspring. Technology that modifies genes in sperm eggs or embryos remains vehemently opposed because of its controversial nature. Malaysia stands with numerous other nations without sufficient laws that control CRISPR usage with human embryos (Polcz & Lewis, 2016). The ability to create genetically designed future generations through unintentional outcomes sparks ethical, religious and evolutionary human evolution study debates. (Polcz & Lewis, 2016; Resnik, 2020).

Malaysia's religious communities, comprising Muslims, Buddhists, Hindus, and Christians, demonstrate different opinions about gene editing. Islamic bioethics guides Malaysia's political decisions by allowing medical treatments that prevent damage to patients and create positive health outcomes. Islamic jurisprudence views the transformation of God's creation (fitrah) together with unpredictable lasting alterations as unacceptable. The National Fatwa Council of Malaysia must provide official guidance regarding CRISPR since scientists, religious scholars, and bioethicists must begin essential discussions about ethical directions (Isa *et al*., 2019).

CRISPR's healthcare delivery faces two primary difficulties, including ethical and equal patient coverage. The availability of CRISPR-based treatments in Malaysia must address the problem of providing equal access to all socioeconomic strata. Gene therapy treatments prove to be both financially expensive and technologically complex, which creates an opportunity for healthcare disparities between affluent citizens who have access to emerging medical solutions and those who do not (Wong *et al*., 2023). Universal healthcare principles and social justice demand that the Malaysian government develop subsidies and regulatory frameworks to spread CRISPR benefits throughout society without prejudice toward economic status.

Malaysian society heavily relies on public perception to determine whether it will accept or reject CRISPR technology. Responses from Southeast Asian citizens showed 60% support for medical treatment gene-editing, although only 30% approved its use during human embryo development (Selvakumar *et al*., 2022). Many people back therapeutic applications of CRISPR, yet they doubt using the technology to modify the germline. Public awareness initiatives, governmental transparency

measures, and user-involved policy structures help solve false information while providing citizens with better means to understand CRISPR applications in Malaysian medical care.

Limitation

This research examines the potential of CRISPR in cancer treatment and its implications for medical education in Malaysia, acknowledging several limitations. It relies on secondary sources, such as existing publications, clinical studies, and policy reports, which may not reflect the latest findings or unpublished data. The rapid evolution of gene editing technology, along with potential breakthroughs or regulatory changes, could impact the study's conclusions. Additionally, the lack of region-specific data on Malaysian medical institutions and CRISPR research made it challenging to assess Malaysia's readiness for CRISPR integration. The study's comparative analysis with high-income countries is limited by differences in resources and infrastructure. Although ethical, religious, and legal aspects of CRISPR in Malaysia are addressed, the absence of survey data from the public or medical students is a gap. Future research should include qualitative interviews or surveys to explore acceptance and feasibility. Despite these limitations, the study provides a valuable foundation for understanding CRISPR's role in cancer care and offers a roadmap for future research and policy discussions.

Conclusion

The implementation of CRISPR-Cas9 technology in Malaysia's healthcare system holds the potential to revolutionize cancer treatment by providing targeted therapies that directly address genetic causes of cancer, unlike traditional chemotherapy or radiotherapy. With rising cancer incidences, particularly nasopharyngeal carcinoma, colorectal cancer, and liver cancer, CRISPR offers a promising alternative that could improve treatment outcomes and lower mortality rates. However, challenges include high costs, lack of expertise, and insufficient regulatory frameworks.

This study reveals that Malaysian medical education is unprepared to incorporate CRISPR technology, lacking practical gene-editing training and clinical genomic programs, which are already established in institutions across the US, Europe, and China. For Malaysia to remain competitive in biomedical advancements, reforms in medical education are necessary, including curricula focused on precision oncology and CRISPR-based therapies.

Ethical concerns, particularly around germline genetic modifications, and the absence of clear regulatory guidelines further complicate CRISPR adoption. Diverse religious and cultural perspectives on genetic interventions add to the complexity. A National Bioethics Committee is essential to guide ethical standards and policies.

To fully integrate CRISPR into cancer care, Malaysia must invest in education, research, and regulatory frameworks. Collaboration between the government, private sector, and academia is crucial to reduce costs and develop localized treatments. Medical universities should provide hands-on CRISPR training and establish global academic partnerships to foster expertise in genomic medicine, ultimately positioning Malaysia as a leader in Southeast Asia's genetic healthcare.

Conflict of Interest

The author(s) declare that there is no conflict of interest regarding the publication of this article.

Acknowledgement

Gratitude is extended to all those who supported and contributed to the completion of this work.

References

Alamillo, J. M., López, C. M., Rivas, F. J. M., Torralbo, F., Bulut, M., & Alseekh, S. (2023). Clustered regularly interspaced short palindromic repeats/CRISPR-associated protein and hairy roots: a perfect match for gene functional analysis and crop improvement. *Current Opinion in Biotechnology*, *79*, 102876. https://doi.org/10.1016/j.copbio.2022.102876

Asmamaw, M., & Zawdie, B. (2021). Mechanism and applications of CRISPR/Cas-9-mediated genome editing. *Biologics: Targets and Therapy*, 353-361. https://doi.org/10.2147/BTT.S326422

Barbosa, S., Toe, L. P., Thizy, D., Vaz, M., & Carter, L. (2021). Engagement and social acceptance in genome editing for human benefit: Reflections on research and practice in a global context. *Wellcome Open Research*, *5*, 244. https://doi.org/10.12688/wellcomeopenres.16260.2

Bender, G., Fahrioglu Yamaci, R., & Taneri, B. (2021). CRISPR and KRAS: a match yet to be made. *Journal of biomedical science*, *28*(1), 77. https://doi.org/10.1186/s12929-021-00772-0

Geethakumari, P. R., Ramasamy, D. P., Dholaria, B., Berdeja, J., & Kansagra, A. (2021). Balancing quality, cost, and access during delivery of newer cellular and immunotherapy treatments. *Current Hematologic Malignancy Reports*, *16*(4), 345-356. https://doi.org/10.1007/s11899-021-00635-3

Goetz, L. H., & Schork, N. J. (2018). Personalized medicine: motivation, challenges, and progress. *Fertility and Sterility*, *109*(6), 952-963. https://doi.org/10.1016/j.fertnstert.2018.05.006

Hasbullah, H. H., & Musa, M. (2021). Gene therapy targeting p53 and KRAS for colorectal cancer treatment: a myth or the way forward?. *International Journal of Molecular Sciences*, *22*(21), 11941. https://doi.org/10.3390/ijms222111941

Ho, P. J., Yeoh, Y. S., Miao, H., Lim, S. H., Tan, E. Y., Tan, B. K. T., ... & Hartman, M. (2021). Cohort profile: The Singapore Breast Cancer Cohort (SGBCC), a multi-center breast cancer cohort for evaluation of phenotypic risk factors and genetic markers. *PLoS One*, *16*(4), e0250102. https://doi.org/10.1371/journal.pone.0250102

Isa, N. M., Zulkifli, N. A., & Man, S. (2020). Islamic perspectives on CRISPR/Cas9-mediated human germline gene editing: a preliminary discussion. *Science and Engineering Ethics*, *26*(1), 309-323. https://doi.org/10.1007/s11948-019-00098-z

Jafri, W., & Kamran, M. (2019). Hepatocellular carcinoma in Asia: a challenging situation. *Euroasian Journal of Hepato-Gastroenterology*, *9*(1), 27. https://doi.org/10.5005/jp-journals-10018-1292

Kalidasan, V., & Das, K. T. (2021). Is Malaysia ready for human gene editing: A regulatory, biosafety and biosecurity perspective. *Frontiers in Bioengineering and Biotechnology*, *9*, 649203. https://doi.org/10.3389/fbioe.2021.649203

Kelly, M. M., Martin-Peters, T., & Farber, J. S. (2024). Secondary Data Analysis: Using existing data to answer new questions. *Journal of Pediatric Health Care*, *38*(4), 615-618. https://doi.org/10.1016/j.pedhc.2024.03.005

Li, T., Li, S., Kang, Y., Zhou, J., & Yi, M. (2024). Harnessing the evolving CRISPR/Cas9 for precision oncology. *Journal of Translational Medicine*, *22*(1), 749. https://doi.org/10.1186/s12967-024-05570-4

Liu, W., Li, L., Jiang, J., Wu, M., & Lin, P. (2021). Applications and challenges of CRISPR-Cas gene-editing to disease treatment in clinics. *Precision Clinical Medicine*, *4*(3), 179-191. https://doi.org/10.1093/pcmedi/pbab014

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *All Ireland Journal of Higher Education*, *9*(3). https://doi.org/10.62707/aishej.v9i3.335

Mazhar, S. A., Anjum, R., Anwar, A. I., & Khan, A. A. (2021). Methods of data collection: A fundamental tool of research. *Journal of Integrated Community Health*, *10*(1), 6-10. https://doi.org/10.24321/2319.9113.202101

National Cancer Institute (2022). *CAR T cells: Engineering immune cells to treat cancer*. [online] National Cancer Institute. https://www.cancer.gov/about-cancer/treatment/research/car-t-cells

Nicol, D., Eckstein, L., Morrison, M., Sherkow, J. S., Otlowski, M., Whitton, T., ... & McWhirter, R. E. (2017). Key challenges in bringing CRISPR-mediated somatic cell therapy into the clinic. *Genome Medicine*, *9*(1), 85. https://doi.org/10.1186/s13073-017-0475-4

Norsa'adah, B., Rampal, K. G., & Amin, R. M. (2021). Time taken for symptom recognition, first consultation, diagnosis and first definitive treatment and its associated factors among women with breast cancer. *Asian Pacific Journal of Cancer Prevention: APJCP*, *22*(11), 3623. https://doi.org/10.31557/apjcp.2021.22.11.3623

Pederson, L. L., Vingilis, E., Wickens, C. M., Koval, J., & Mann, R. E. (2020). Use of secondary data analyses in research: Pros and Cons. *Journal of Addiction Medicine and Therapeutic Science*, *6*(1), 058-060. https://doi.org/10.17352/2455-3484.000039

Polcz, S., & Lewis, A. (2016). CRISPR-Cas9 and the non-germline non-controversy. *Journal of Law and the Biosciences*, *3*(2), 413-425. https://doi.org/10.1093/jlb/lsw016

Rasul, M. F., Hussen, B. M., Salihi, A., Ismael, B. S., Jalal, P. J., Zanichelli, A., ... & Taheri, M. (2022). Strategies to overcome the main challenges of the use of CRISPR/Cas9 as a replacement for cancer therapy. *Molecular Cancer*, *21*(1), 1-30. https://doi.org/10.1186/s12943-021-01487-4

Resnik, D. (2015). *What is ethics in research & why is it important? [Online] National institute of environmental health sciences*. https://www.niehs.nih.gov/research/resources/bioethics/whatis

Samori, Z. & Rahman, F.A. (2024). Beyond Hopes, Beyond Cures: A Proposed Malaysian Regulatory Framework for Somatic Gene Therapy in Human. *International Journal of Religion*, *5*(10), 4132–4155. https://doi.org/10.61707/btmq4740

Selvakumar, S. C., Preethi, K. A., Ross, K., Tusubira, D., Khan, M. W. A., Mani, P., ... & Sekar, D. (2022). CRISPR/Cas9 and next generation sequencing in the personalized treatment of Cancer. *Molecular Cancer*, *21*(1), 83. https://doi.org/10.1186/s12943-022-01565-1

Uddin, F., Rudin, C. M., & Sen, T. (2020). CRISPR gene therapy: applications, limitations, and implications for the future. *Frontiers in Oncology*, *10*, 1387. https://doi.org/10.3389/fonc.2020.01387

Wolyniak, M. J., Austin, S., Bloodworth III, L. F., Carter, D., Harrison, S. H., Hoage, T., ... & Challa, A. K. (2019). Integrating CRISPR-Cas9 technology into undergraduate courses: perspectives from a National Science Foundation (NSF) workshop for undergraduate faculty, June 2018. *Journal of Microbiology & Biology Education, 20*(1), 10-1128. https://doi.org/10.1128/jmbe.v20i1.1702

Wong, C. H., Li, D., Wang, N., Gruber, J., Lo, A. W., & Conti, R. M. (2023). The estimated annual financial impact of gene therapy in the United States. *Gene Therapy*, *30*(10), 761-773. https://doi.org/10.1038/s41434-023-00419-9

Wong, L. P., Lai, L. L., See, M. H., Alias, H., Danaee, M., Ting, C. Y., & Tok, P. S. K. (2021). Psychological distress among cancer survivors during implementation of a nationwide Movement Control Order over the COVID-19 pandemic. *Supportive Care in Cancer*, *29*(10), 6087-6097. https://doi.org/10.1007/s00520-021-06182-0

Xiaoshuai, L., Qiushi, W., & Rui, W. (2022). Advantages of CRISPR-Cas9 combined organoid model in the study of congenital nervous system malformations. *Frontiers in Bioengineering and Biotechnology*, *10*, 932936. https://doi.org/10.3389/fbioe.2022.932936

Chan, Y. M., Ismail, M. Z. H., & Khaw, W. F. (2023). Factors influencing the prevalence of cervical cancer screening in Malaysia: a nationwide survey. *BMC Women's Health*, *23*(1), 389. https://doi.org/10.1186/s12905-023-02553-3

Loh, E. Y. X., Ab Ghani, A., & Ahmad, R. (2023). Regulatory oversight of cell and gene therapy products in Malaysia. In *Regulatory Aspects of Gene Therapy and Cell Therapy Products: A Global*

Perspective (pp. 181-195). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-34567-8_10

Zhang, Y., Zhao, G., Ahmed, F. Y. H., Yi, T., Hu, S., Cai, T., & Liao, Q. (2020). In silico method in CRISPR/Cas system: an expedite and powerful booster. *Frontiers in Oncology*, *10*, 584404. https://doi.org/10.3389/fonc.2020.584404

Su, Z. Y., Siak, P. Y., Leong, C. O., & Cheah, S. C. (2023). The role of Epstein–Barr virus in nasopharyngeal carcinoma. *Frontiers in Microbiology*, *14*, 1116143. https://doi.org/10.3389/fmicb.2023.1116143

Park, H., Yu, S. and Koo, T. (2025). Gene editing in cancer therapy: Overcoming drug resistance and enhancing precision medicine. *Cancer Gene Therapy*, *32*(9), 1451–1462. https://doi.org/10.1038/s41417-025-00567-x

Tang, S., Chen, X., Tong, X., & Zhu, L. (2025). Overcoming the delivery challenges in CRISPR/Cas9 gene editing for effective cancer treatment: A review of delivery systems. *International Journal of Medical Sciences*, *22*(14), 3625. https://doi.org/10.7150/medsci.3625

Rauf, M. A., Rao, A., Sivasoorian, S. S., & Iyer, A. K. (2025). Nanotechnology-based delivery of CRISPR/Cas9 for cancer treatment: A comprehensive review. *Cells*, *14*(15), 1136. https://doi.org/10.3390/cells14151136