

Systematic Review Article

Therapeutic Targeting of MOAP-1 in Cancer: A Systematic Review of Current Approaches and Future Directions

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Abstract: The Modulator of Apoptosis 1 (MOAP-1) protein, a crucial regulator of apoptosis, has recently attracted considerable interest in oncology research. Its potential as a therapeutic target in bladder, breast, and non-small cell lung cancer (NSCLC) offers intriguing new therapeutic approaches. This comprehensive review consolidated work on MOAP-1's role in cancer biology, notably as a therapeutic target. A systematic review was conducted by searching digital databases for studies. Based on inclusion and exclusion criteria, ten articles were thoroughly assessed. Emerging evidence links MOAP-1 to bladder cancer chemosensitivity and MOAP-1-dependent chemosensitization of breast cancer mediated by phenylquinazoline derivatives. In addition, apoptosis in breast cancer cells was induced by α -mangostin, a potential therapeutic drug targeting MOAP-1 and BCL-XL interaction. Studies showed MOAP-1's importance in NSCLC, with its upregulation in the cancer cells as a potential treatment. This review also highlights the role of miR-25 as a cellular regulator of MOAP-1 and its implication for MOAP-1-mediated therapeutics. The intricate control of MOAP-1 in cancer highlights the need for more research to understand its function and regulation across cancer types completely. MOAP-1's tumor suppressor activity suggests it could be a therapeutic target, as evidenced by current research findings, which is likely to

spur further research into MOAP-1-targeted cancer treatments. This systematic review fills a gap in the literature by bringing together a variety of study findings to promote a deeper understanding of MOAP-1 and its therapeutic potential.

Keywords: tumor, malignancy, medicine, cancer, chemotherapy, drug discovery

1. Introduction

The Modulator of Apoptosis 1 (MOAP-1), codified by the *MOAP1* gene, played an indispensable role in instigating and culminating apoptosis, serving as an integral component of the cellular endogenous death apparatus^[1–3]. A burgeoning collection of scientific discourse has brought to light that distortions in the functional capacity or the expression quotient of this protein contributed significantly to the etiopathogenesis and advancement of human cancers^[4–7].

The concept of therapeutically targeting MOAP-1 in oncology stems from a thorough comprehension of its pivotal role in the cellular balance between survival and death^[8]. This equilibrium is frequently disrupted in oncogenesis, tilting towards survival and facilitating uncontrolled cellular proliferation^[9,10]. This is especially crucial with the rapid development of omics in the drug discovery process, such as the use of Support Vector Machine – Recursive Feature Elimination (SVM-RFE) as the selected feature selection method in the lung cancer multi-omics dataset integrated from three single omics datasets comprising genomics, transcriptomics, and epigenomics, and assess the quality of the selected feature subsets using SDAE and VAE deep learning classifiers^[11]. The unprecedented COVID-19 pandemic has brought such a new challenge to biomedical scientists to push the frontier of biomedical research to innovate new molecules or pathways that could cut down the test-tube to market timeline^[12–14]. This has also impacted cancer drug discovery by moving towards the use of in-silico modeling to elucidate the mechanistic pathway of newly found small molecules or proteins^[15,16] that have good potential as vaccines and cancer therapeutics^[17,18].

In the context of small molecule inhibitors targeting MOAP-1, several compounds that exhibit a high degree of specificity have been identified^[19,20]. These inhibitors interact directly with MOAP-1, altering its conformation and modulating its interactions with other proteins integral to the apoptotic process. The primary function of these molecules is to amplify the function of MOAP-1 and enhance its expression, thereby reinstating apoptosis in cancer cells^[21,22]. This strategy is advantageous due to its specificity and the minimization of off-target effects^[23,24], although challenges such as the development of resistance and the complexity of apoptotic signaling networks must be acknowledged^[25–31].

Strategic manipulation of functional properties or expression levels of MOAP-1 could potentially shift the balance toward apoptosis, thus opening avenues for selective elimination of malignant cells^[32,33]. It is worth mentioning that aspects of molecular biology research of colorectal cancer (CRC), Yunos *et al.*^[34] emphasize the genetic mutations linked to Lynch

syndrome, a CRC precursor, and present a rapid screening method for early CRC detection in affected individuals^[35]. While neither study by Nasir *et al.*^[36] nor Yunos *et al.*^[34] directly addresses MOAP-1 or apoptosis, the strategic alteration of molecules like circEPHB4 or MMR genes might sway the balance towards apoptosis, a form of programmed cell death, paving the way for targeted cancer therapies.

This systematic review examines all available information on the therapeutic targeting of MOAP-1 in cancer. Various strategies are explored, including the use of small molecule inhibitors of MOAP-1, with a critical appraisal of their merits and shortcomings. The potential advantages of targeting MOAP-1 in cancer treatment are being examined, especially when combined with other anticancer therapies^[37–39]. Instances of effective MOAP-1 targeting implementation from real-world situations, both preclinical and clinical, are described. The difficulties that may arise when targeting MOAP-1 are emphasized, including the possibility of deleterious consequences from MOAP-1 inhibition. An exploration of several approaches to overcoming these challenges is presented. Finally, the review stimulates debate regarding future research areas and potential advances in MOAP-1 targeting. This is a comprehensive summary of the possible benefits and drawbacks of MOAP-1 targeting in clinical use. This study fills an essential gap in the existing literature by providing an in-depth overview of the present status of research and future possibilities. It serves as a comprehensive resource, laying the groundwork for future scientific research into the promising but challenging subject of MOAP-1 targeting in cancer treatment.

2. Materials and Methods

This systematic review was conducted by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines^[40]. The search terms and databases used are presented in Table 1. Consideration was given to investigations focusing on MOAP-1 as a therapeutic target in oncology, inclusive of both preclinical and clinical studies. Conversely, studies were excluded that did not centralize MOAP-1 or oncology therapy, were not accessible in English, or were not published in peer-reviewed journals. Additionally, a manual search of the reference lists of pertinent articles was undertaken to identify supplementary studies. Relevant data were extrapolated from each included investigation, encompassing elements such as study design and models used. Subsequent data synthesis involved the collation, synthesis, and analysis of these data to identify recurrent themes, trends, and patterns relating to MOAP-1 targeting in oncology therapy.

Table 1. Search terms used for this systematic review.

Database	Search terms
Web of Science	ALL=("MOAP-1" OR "Modulator of apoptosis 1") AND ALL=("cancer" OR "tumor" OR "neoplasm" OR "carcinoma" OR "oncology") AND ALL=("targeting" OR "inhibition" OR "therapy" OR "treatment")
SCOPUS	("MOAP-1" OR "Modulator of apoptosis 1") AND ("cancer" OR "tumor" OR "neoplasm" OR "carcinoma" OR "oncology") AND ("targeting" OR "inhibition" OR "therapy" OR "treatment")

Database	Search terms
PubMed	("MOAP-1" OR "Modulator of apoptosis 1") AND ("cancer" OR "tumor" OR "neoplasm" OR "carcinoma" OR "oncology") AND ("targeting" OR "inhibition" OR "therapy" OR "treatment")

3. Results and Discussion

For this systematic review, a total of 10 articles met the criteria and were subsequently included for in-depth analysis (Figure 1). The summary of the included study is presented in Table 2. Figure 2 shows the summary of the target protein.

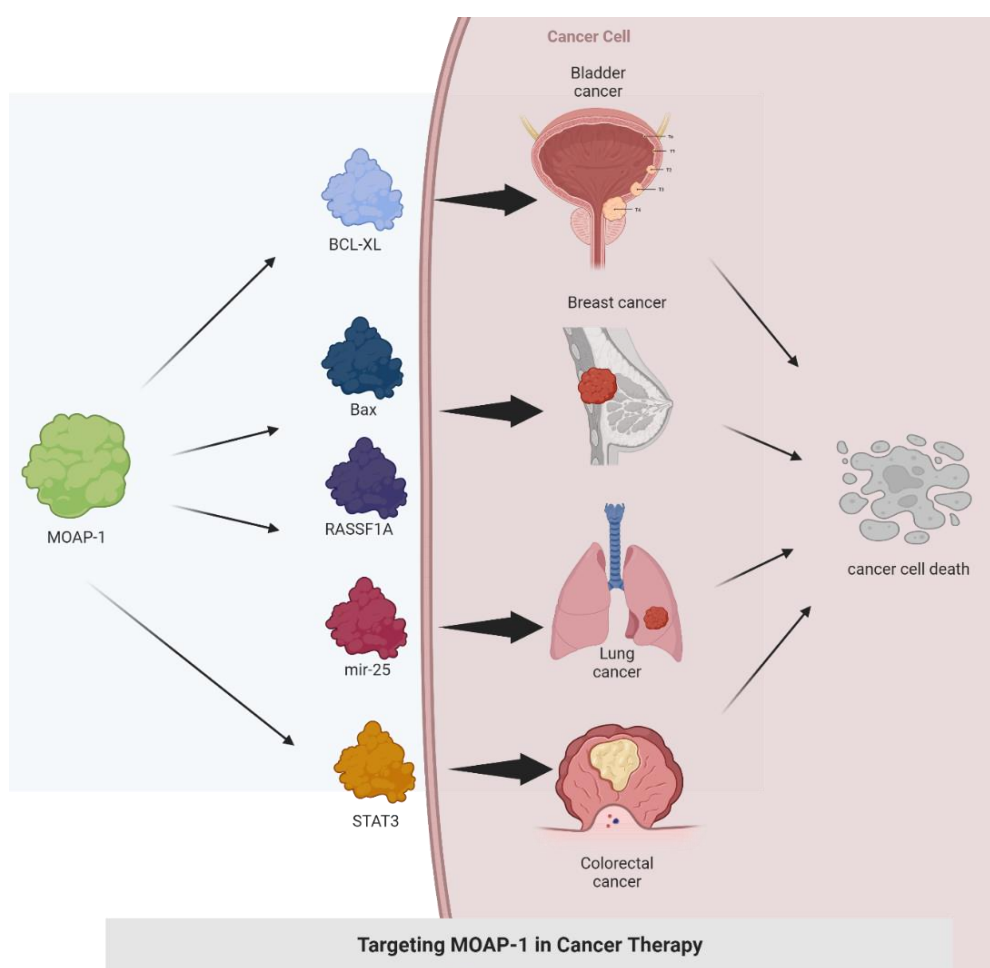


Figure 1. Target proteins of MOAP-1 mediated cancer therapy.

Three out of ten studies reported the role of MOAP-1 in breast cancers, while two studies reported the involvement of MOAP-1 in lung cancer. Interestingly, there are two articles published in 2015 and 2021 involving more than a single type of cancer in their studies. The remaining selected articles involved an investigation of the role of MOAP-1 in either bladder cancer, ovarian cancer, or colorectal cancer.

In the current milieu of MOAP-1 targeting in oncology therapy, therapeutic strategies largely encompass the use of small-molecule inhibitors, genetic interventions, and antibody-based therapies^[41–44]. These interventions intend to amplify the function of MOAP-1 and enhance its expression, to reinstate apoptosis in neoplastic cells^[45]. Several small molecule inhibitors that possess the ability to selectively modulate the function of MOAP-1 have been identified. These molecules predominantly function by interacting directly with MOAP-1, altering its conformation, or modulating its ability to interact with other proteins integral to the apoptotic process. Furthermore, antibody therapies targeting MOAP-1 are another therapeutic strategy^[46,47]. These therapies involve the use of antibodies designed to recognize and bind to MOAP-1, potentially modulating its activity^[48,49]. The advantage of antibody therapies lies in their high specificity and the possibility of direct targeting of MOAP-1, reducing the likelihood of off-target effects. However, the development and clinical validation of such therapies are challenging, often requiring significant financial investment and rigorous testing^[50,51].

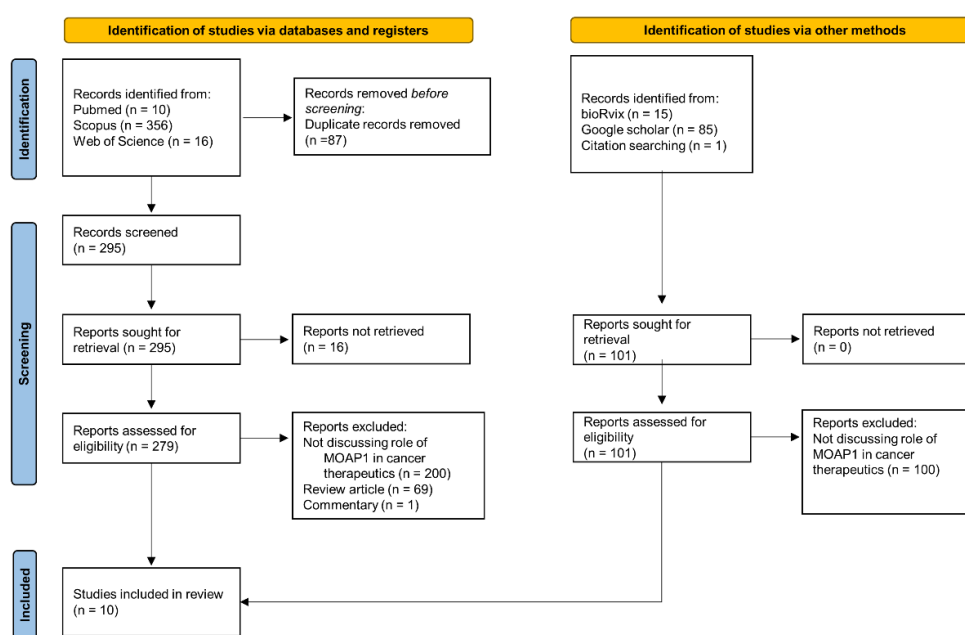


Figure 2. PRISMA flow diagram showing the selection process of the studies included in the review.

These approaches of MOAP-1 targeting in cancer therapy demonstrate substantial advantages, mainly encompassing specificity and minimisation of off-target effects^[36, 52]. Nevertheless, challenges persist. These include the evolution of resistance, the challenge of delivering therapies directly to the tumor locale, potential toxicity, and the complexity of the apoptotic signaling networks, which may compensate for the inhibition of a singular component like MOAP-1. These critical insights derived from the selected articles form the core results of our systematic review, as presented in Table 2, laying the groundwork for further exploration and discussion.

Table 2: Reported aims and findings related to MOAP-1 of included studies.

Year	Cancer type	Aim	Study type	Important findings related to MOAP-1	Ref.
2007	Bladder cancer	To build prediction models using growth inhibition data and gene expression to estimate chemosensitivity of bladder cancer cells towards different combinations of gemcitabine, cisplatin and paclitaxel	In vitro (40 urothelial cancer cell lines)	<ul style="list-style-type: none"> As one of the predictive genes for cisplatin (two out of three predictive models) 	[53]
2020	Breast cancer	To investigate the effects of MOAP-1, Bax, and RASSF1A (MBR) expression via tricistronic expression vector on chemosensitisation of breast cancer cells	In vitro (MCF-7, MCF-7-CR and BMET05 cell lines) In vivo (female NOD SCID Gamma mice, n=10 per group for vector only and MBR-containing vector)	<ul style="list-style-type: none"> Transient expression of MBR promotes chemosensitisation of breast cancer cells (including MCF-7 and MCF-7-CR) against tested drugs such as etoposide and cisplatin Increased apoptosis and inhibition of growth observed in MCF-7 cells transfected with MBR expression vector MBR stable clone promoted chemosensitisation in 17β-estradiol stimulated mouse xenograft model Reduced tumor volume and weight Increased apoptotic cell death in excised tumor (via TUNEL staining) 	[54]
2022	Breast cancer	To evaluate anticancer and pro-apoptotic activities of phenylquinazoline derivatives mediated through MBR signalling pathways	In vitro (MCF-7 and MCF-7-CR cell lines)	<ul style="list-style-type: none"> SMS-IV-20 and SMS-IV-40 increased chemosensitisation of MBR stable clones in MCF-7 and MCF-7-CR cell lines 	[3]
2022	Breast cancer (and immortalised human keratinocyte)	To evaluate anticancer potential of α -mangostin and its effects on mitochondria-associated molecules, endogenous and	In vitro (MCF-7, MCF-7-CR and HaCaT cell lines)	<ul style="list-style-type: none"> α-mangostin treated cells expressed dose-dependent upregulation of endogenous MOAP-1 proteins along with downregulation of BCL-XL proteins Three days treatment of α-mangostin in spheroids expressing HA-MOAP-1 resulted in approximately 	[8]

Year	Cancer type	Aim	Study type	Important findings related to MOAP-1	Ref.
		overexpressed mitochondria-associated proteins (including MOAP-1 and BCL-XL)		<ul style="list-style-type: none"> 90% reduction of cell viability • α-mangostin activates MOAP-1 mediated apoptosis 	
2015	Lung cancer	To determine the role of miR-25 in NSCLC	<p>In vitro (A549, H1299, H1275 and Hcc827 cell lines)</p> <p>In vivo (Four-week-old BALB/c nude mice injected with A549 cells subcutaneously, n = 8 per group)</p> <p>Human (n = 81 NSCLC patients, n = 41 healthy control)</p>	<ul style="list-style-type: none"> • MOAP-1 is a novel target of miR-25 • Inhibition of miR-25 reduced cell proliferation and promoted apoptosis via upregulation of MOAP-1, Bax and cytosolic cytochrome c • Significantly increased MOAP-1 expression in tumors treated with miR-25 antagonist compared to controls • miR-25 inhibition reduced tumor growth and increased apoptosis via upregulation of MOAP-1 • miR-25 expression was increased in plasma of NSCLC patients as compared to control • Comparing stages, those in Stage III and IV had higher expression of miR-25 as compared to Stage I/II • No significant differences of miR-25 expression between Stage III and IV 	[55]
2023	Lung cancer	To investigate the role of MOAP-1 in NSCLC progression	In vitro (H292, A549, H226, H299 and H460 cell lines)	<ul style="list-style-type: none"> • Significantly decreased expression of MOAP-1 expression in H460 and A549 cells (at gene and protein levels) as compared to normal cell line (BEAS-2B) • Increased expression of MOAP-1 via transfection with associated plasmids decreased proliferative 	[2]

Year	Cancer type	Aim	Study type	Important findings related to MOAP-1	Ref.
				<p>capacity of A549 and H460 cells.</p> <ul style="list-style-type: none"> • Potential role of MOAP-1 in the development of NSCLC through mediation of immune cell infiltration and epithelial-mesenchymal transition • TRIM68 interacts with MOAP-1 as observed in multiple cell lines (HEK293, A549 and H460) and stabilizes MOAP-1 expression 	
			In vivo (Six-week-old BALB/c nude mice injected with A549 cells subcutaneously, n = 5 per group)	<ul style="list-style-type: none"> • Overexpression of MOAP-1 significantly reduced the tumor volume, growth rates, and tumor weights as compared to control group • Decreased expression of KI-67 (marker for tumor cell proliferation) observed in mice with MOAP-1 overexpression 	
			Human (Data retrieved from TCGA database)	<ul style="list-style-type: none"> • RNA-seq data from The Cancer Genome Atlas (TCGA) revealed decreased expression of MOAP-1 during lung cancer progression 	
2018	Colorectal cancer	To examine the role of STAT3, miR-572, and MOAP-1 in colorectal cancer progression	In vitro (LS174T, SW620, HT29, LOVO, HCT116 and SW480 cell lines)	<ul style="list-style-type: none"> • Overexpression of miR-572 via transfection assay decreased expression of MOAP-1 expression significantly in LS174T and SW620 cells STAT3 upregulated miR-572 expression and miR-572 promoted LS174T cells' migration and invasion • Treatment with miR-572 inhibitors elevated MOAP-1 expression in HCT116 and SW480 cells Knockdown of STAT3 reduced cell growth in SW480 cells but the addition of miR-572 mimics MOAP-1 siRNA and restored cell proliferation STAT3 induced CRC progression via miR-572-MOAP-1 pathway 	[56]

Year	Cancer type	Aim	Study type	Important findings related to MOAP-1	Ref.
			Human (n = 40 tissue samples from colorectal resection)	<ul style="list-style-type: none"> Significant negative correlation between <i>STAT3</i> and <i>MOAP-1</i> gene expression (p = 0.0005) Inverse relationship between MOAP-1 protein and miR-572 expression as determined by Western blot and qRT-PCR 	
2017	Ovarian cancer	To explore how the proapoptotic protein MOAP-1 is involved in ovarian cancer resistance to cisplatin	In vitro (PC-3, H1299, ES-2, SK-OV-3, HeLa and 293T cell lines)	<ul style="list-style-type: none"> Knockdown of UBR5 enhanced MOAP-1 stability Downregulation of UBR5 resulted in MOAP-1 accumulation and induced cell death via intrinsic apoptosis pathway UBR5-MOAP-1 pathways involved in development of resistance in ovarian cancer 	[57]
			Human (n = 20 frozen specimens (from patient with serous epithelial ovarian cancer)	<ul style="list-style-type: none"> Significantly higher UBR5 expression in ovarian cancer tissues samples classified as "cisplatin resistant" as compared to cancer tissue samples derived from "cisplatin responsive" patients Lower MOAP-1 expression in cisplatin-resistance cancer tissue samples 	
2015	Multiple	To investigate the role of MOAP-1 as a tumor suppressor protein in multiple cancer types	In vitro (Neuroblastoma: Be(2)c, GoTo, LAN01, KAN, Nub7, SKNAS, SH-SY5Y, DAOY; Melanoma: A2058, WM35, WM793; Bone: SAOS-2, U2OS; Lung: H1299, A549; Liver cancer: HepG2, Hep3B; Colon cancer: HCT116, HT-29, SW480, T84, Caco-2; Leukemia: J77 (T-ALL), KG1 (AML), C1 (pre-BALL), SEM (MLL); Pancreatic cancer: CAPAN-2;	<ul style="list-style-type: none"> Overexpression of MOAP-1 in multiple cell lines resulted in reduced tumorigenesis and increased expression of genes involved in regulatory pathways (e.g., apoptosis, metabolism and microtubule) <i>MOAP-1</i> expression was detected in p53-positive cell lines (U2OSm HCT116, ZR-75, IMR-32 and PANC1) but at reduced/none in p53-null cell lines (SAOS-2 and SKOV3), cell lines with p53 frameshift mutation/rearrangement 	[58]

Year	Cancer type	Aim	Study type	Important findings related to MOAP-1	Ref.
			Breast cancer: SKBR3, MDA-MB468, MDA MB-231, BT-549, BT-20; Ovarian cancer: SKOV3, OVCAR-3)	(Caco-2 and CAPAN-2), and p53-mutant cell lines (SKBR3, MDA-MB-468, MDA MB-231, BT-549, BT-20 and OVCAR-3)	
	Neuroblastoma		Human (n = 88)	<ul style="list-style-type: none"> Higher survival rates among patients with higher expression of <i>MOAP-1</i> or <i>RASSF1A</i> compared to those with lower expression of either gene 	
2021	Multiple	To investigate the role of MOAP-1 in the regulation of p62-Keap-1-Nrf2 signalling under stress condition	In vitro (LO2 human hepatocytes; liver cancer cells: HepG2, Huh-1, JH5 and JH7; cervical cancer HeLa)	<ul style="list-style-type: none"> Exposure to oxidative stressor (e.g. Arsenic trioxide) induced formation of p62 bodies which also promoted MOAP-1 recruitment in multiple cell lines tested 	[1]
			In vivo (Male C57/BL6 mice)	<ul style="list-style-type: none"> MOAP-1-deficient mice exhibit an elevated tumor burden with excessive levels of p62 bodies and Nrf2 signaling in a diethylnitrosamine (DEN)-induced hepatocarcinogenesis model 	

3.1. MOAP-1 as a Tumor Suppressor Protein

In Law *et al.*^[58], MOAP-1 was emphasized as a tumor suppressor protein, highlighting the common loss of MOAP-1 expression in several cancers and linking this loss to tumorigenesis. Complementing the findings, Xu *et al.*^[2] proposed that increased MOAP-1 expression inhibits lung cancer cell proliferation and suppresses the epithelial-mesenchymal transition process in lung cancer cells. The role of MOAP-1 was further unravelled in colorectal carcinoma progression in a study by Wang *et al.*^[56], which identified a novel pathway involving STAT3, miR-572, and MOAP-1. Similarly, Wu *et al.*^[55] reported miR-25 targets and downregulates MOAP-1 in the context of lung cancer, promoting cell proliferation and reducing apoptosis in NSCLC cells. Both studies underscore the potential of miRNAs in regulating MOAP-1 levels and their consequential impact on cancer progression.

3.2. Role of MOAP-1 in Specific Cancer Types

Targeting MOAP-1 in cancer therapy could offer several potential benefits. Firstly, this approach is highly selective, preferentially inducing death in cancer cells over normal cells^[19]. Moreover, this approach may serve to surmount resistance to other therapy modalities, such as chemotherapy or radiotherapy, by triggering apoptosis via a distinct, synergistic pathway^[59–61]. Importantly, it could prove especially effective for those cancers where there is a functional deficiency or reduced expression of MOAP-1, thereby lending itself to a more personalised treatment strategy. Lately, a resurgent interest in the MOAP-1 gene has been noted within the scientific community, attributable to its potential significance in the onset of several human cancers. As a protein that interacts with members of the BCL-2 protein family which regulates apoptosis, MOAP-1 has been pinpointed as a crucial participant as an inhibitor of tumorigenesis^[58]. Furthermore, alterations in MOAP-1 expression levels have been linked to diverse cancer types, including bladder^[53], breast^[3,8,54], and non-small cell lung cancer (NSCLC)^[2, 55].

3.3. Regulation of MOAP-1 by miRNAs

One intriguing study focusing on bladder cancer devised an innovative model for predicting molecular chemosensitivity. This model was constructed utilising global gene expression and GI50 data derived from 40 human urothelial cancer cell lines. Employing a unique mathematical technique known as MiPP probabilities, a correlation was uncovered between MOAP-1 and several other genes, with respect to chemosensitivity to three chemotherapeutic agents. This revelation underscores the potential of MOAP-1 as a candidate for future therapeutic strategies^[53]. Lee *et al.*^[54] have delivered robust evidence in the context of breast cancer, revealing that expressing MOAP-1 along with Bax and RASSF1A significantly enhances the chemosensitivity of cancer cells. Similar findings were also reported in a study by Simon *et al.*^[8], which introduced synthetic phenylquinazoline derivatives as potent activators of apoptosis that increase chemosensitisation in human breast cancer cells by antagonising pro-survival members of the BCL-2 family. An additional study published in 2022 also presented findings that are promising, showing α -mangostin's ability to induce dose-dependent apoptotic cell death and an increase in endogenous MOAP-1 levels^[8].

Together, these studies delineate the complex role of MOAP-1 in cancer cell apoptosis, chemosensitization, and intricate interactions with proteins such as Bax, RASSF1A, and BCL-2^[3]. They also highlight the tumor suppressive role of MOAP-1^[8,58] and the influence of its regulation by miRNAs on the trajectory of cancer progression^[56].

4. Future Perspectives

In the burgeoning field of oncological therapeutics, small molecular inhibitors targeting MOAP-1 have emerged as a beacon of hope. Their merits are manifold. Firstly, these inhibitors are often meticulously designed to interact with MOAP-1, ensuring a

targeted modulation of the protein's activity and thus minimising off-target effects. Owing to their diminutive size, these molecules often boast superior bioavailability, which facilitates their efficient absorption and distribution within the body. Their ability to swiftly penetrate cells allows for rapid therapeutic effects. Furthermore, the synthetic flexibility inherent to these inhibitors provides a robust platform for chemical modifications, optimising their pharmacological properties, enhancing efficacy, and mitigating potential side effects. However, these inhibitors are not without their shortcomings^[58]. Over time, tumor cells may develop resistance, potentially curtailing their long-term efficacy. And, despite their specificity, there remains an ever-present risk of these molecules interacting with unintended proteins or pathways^[62]. Their metabolic instability might necessitate frequent dosing to maintain therapeutic levels, and prolonged use or high doses could induce toxic effects in non-target tissues or organs.

Several approaches have been postulated to address the challenges associated with MOAP-1 targeting. Combination therapies, for instance, where small molecular inhibitors are used alongside other therapeutic agents like supplements, chemotherapy or radiotherapy, might amplify efficacy and counteract resistance^[63–65]. The dawn of personalised medicine allows treatments to be tailored based on the tumor's genetic makeup, enhancing the efficacy of MOAP-1 targeting. Advanced drug delivery systems, such as oncolytic adenoviruses or nanoparticles, promise enhanced delivery of MOAP-1 inhibitors directly to tumor sites, minimising off-target effects and bolstering therapeutic outcomes^[23, 66]. Moreover, the regular monitoring of a tumor's response to treatment can herald early signs of resistance development, allowing for timely therapeutic recalibrations^[67,68].

For clinical application, MOAP-1 targeting offers both potential benefits and drawbacks^[69]. On the one hand, it provides a more precise approach to cancer treatment, zeroing in on a specific molecular pathway implicated in tumorigenesis^[67,70]. This specificity could lead to reduced side effects compared to broader spectrum cancer treatments^[3,54,71]. The potential to overcome resistance mechanisms that tumors develop against conventional therapies and the promise of personalised treatments based on the tumor's specific genetic and molecular profile are other notable benefits^[72]. However, the intricate regulatory networks of MOAP-1's activity can introduce challenges in crafting effective targeting strategies. The specter of resistance development looms large, and despite the specificity of MOAP-1 targeting, off-target effects remain a concern. Additionally, the financial implications of developing and clinically validating MOAP-1 targeting agents might render the treatment less accessible to a wider patient demographic.

The literature suggested that MOAP-1 could be a promising frontier in cancer therapeutics. It demands a holistic understanding of its potential boons and pitfalls. It is paramount that continuous research and clinical trials shape and refine MOAP-1 targeting strategies, ensuring their pinnacle of efficacy and safety for cancer patients.

5. Conclusions

MOAP-1 protein, central to apoptosis, has become a focal point in modern oncology. Its significance in cancers, especially bladder, breast, and NSCLC, is supported by numerous studies. A notable urothelial carcinoma study introduced a predictive model for molecular chemosensitivity, revealing a link between genes, including MOAP-1, and chemosensitivity. In breast cancer research, MOAP-1 has been highlighted as a potential therapeutic target. Studies have shown that synthetic phenylquinazoline derivatives enhance chemosensitisation in breast cancer cells, with MOAP-1 playing a key role. Furthermore, α -mangostin has been found to induce apoptosis by disrupting the MOAP-1 and BCL-XL interaction. For NSCLC, the importance of MOAP-1 is becoming clearer. Enhancing MOAP-1 expression could potentially inhibit NSCLC progression. Interestingly, miR-25 has been identified as a regulator of MOAP-1 expression in NSCLC, promoting cell growth and reducing apoptosis. The current research into MOAP-1 targeting, including small molecule inhibitors, genetic interventions, and antibody therapies, demonstrates promising potential. However, challenges such as tumor resistance, delivery to the tumor locale, and potential toxicity remain. Future research and clinical trials are essential to refine these strategies, ensuring their efficacy and safety. The development of combination therapies, personalised medicine approaches, and advanced drug delivery systems like oncolytic adenoviruses or nanoparticles are promising areas for future exploration to enhance the efficacy of MOAP-1 targeted therapies.

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