

REVIEW ARTICLE

ABO blood type and cancer
susceptibility: Unraveling the complex relationshipPrashanna Koirala¹, Chhiring Sherpa², Rebecca Dangol³, Salina Hona⁴,
Saroj Nepal¹, and Prabin Dawadi^{1,5*}¹Department of Biology, University of Mississippi, Mississippi, United States of America²Experimental Hematology and Cancer Biology, Cincinnati Children's Hospital Medical Center, Ohio, United States of America³Department of Biotechnology, SANN International College, Purbanchal University, Kathmandu, Bagmati, Nepal⁴Division of Neurology, Cincinnati Children's Hospital Medical Center, Ohio, United States of America⁵Department of Microbiology, Tribhuvan University, Kirtipur, Bagmati, Nepal**Abstract**

Different human diseases have been associated with specific blood groups. Numerous studies have promulgated their findings regarding the probable onset of various cancers based on the type of ABO blood group. However, the findings have been conflicting. This review primarily aims to summarize research findings from around the world to investigate the relationship between the risk of cancer occurrence and ABO blood group. Google Scholar, PubMed, Research4Life, and Web of Science were searched to identify relevant papers published before January 2023. Research papers related to common types of cancers were adequately and critically studied to determine the link between ABO blood groups and the risk of developing cancers. The results were ambiguous, as the findings were inconsistent regarding the relationship between ABO blood groups and cancer development. Therefore, more comprehensive research is needed to validate this relationship. This mini-systematic review emphasizes the need for additional thorough investigations to establish a clear correlation because of the inconsistent results.

Keywords: ABO; Blood group; Cancer risk; Relationship**Corresponding author:**Prabin Dawadi
(prabdawadi1993@gmail.com)**Citation:** Koirala P, Sherpa C, Dangol R, Hona S, Nepal S, Dawadi P. ABO blood type and cancer susceptibility: Unraveling the complex relationship. *Microbes & Immunity*. 2025;2(1):45-58. doi: 10.36922/mi.3267**Received:** March 26, 2024**Revised:** October 24, 2024**Accepted:** November 12, 2024**Published Online:** December 31, 2024**Copyright:** © 2024 Author(s). This is an Open-Access article distributed under the terms of the Creative Commons Attribution License, permitting distribution, and reproduction in any medium, provided the original work is properly cited.**Publisher's Note:** AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.**1. Introduction**

The ABO blood groups are polymorphic, antigenic, and genetic substances and consist of four phenotypes: "A," "B," "O," and "AB."¹ The ABO system was the first genetic polymorphism identified in humans and remains one of the major human blood type systems, with major applications in transfusion medicine and organ or tissue transplantation.^{2,3} The term "histoblood group ABO" is used to describe the omnipresent nature of ABO antigens. These blood group antigens are involved in cell signaling, cell recognition, and cell adhesion, which may reflect their potential role in tumorigenesis, metastasis, and prognosis.⁴⁻⁷ Expanding the clinical significance of the ABO blood system beyond immunohematology, transfusion, and transplant medicine is biologically feasible.⁸

Numerous studies have reported associations between blood types and cancer susceptibility. A relationship between the A blood group and gastric cancer was first demonstrated in 1953.⁹ Since then, a higher incidence of the A blood group has been documented in numerous cancers, such as colon, ovarian, and cervical cancers. As cells become malignant, they tend to lose normal blood antigens and gain new tumor-associated antigens.¹⁰ The reduction in normal antigens (A, B, and H) is inversely proportional to the metastatic ability of the tumor.¹¹ Some tumor antigens are true A antigens, while others are A-like antigens, sharing properties similar to A antigens.¹² Therefore, these antigens can be detected on the tumors of patients with blood type A, as they would be recognized as foreign antigens, triggering an immune attack.¹³ However, A or A-like antigens present in tumors are not perceived as foreign in individuals with the A blood group.¹⁴ This may explain why individuals with the A blood group have a higher risk of cancer than those with blood group O.^{15,16} This review attempts to decipher the correlation between the frequency of blood groups and the incidence of different cancers.

1.1. Mechanism of the pathology

1.1.1. Glycosyltransferase activity

The ABO blood grouping system involves antigens, including A, B, and H. The ABO system comprises seven exons containing DNA variants that alter the enzymatic activity of the gene (Figure 1). The gene for the ABO blood group is located on chromosome 9q34, which encodes alleles A and B, resulting in specific glycosyltransferases produced from four non-synonymous variants at nucleotides 526, 703, 796, and 803.¹⁷ The A allele encodes α 1-3 N-galactosaminyltransferase, which catalyzes the covalent linkage of N-acetylgalactosamine to the non-reducing ends of glycans on the glycoproteins of the H antigen expressed in all red blood cells. The B allele encodes another glycosyltransferase called α 1-3-

galactosyltransferase, which transfers D-galactose to the H determinant. However, the O-variant allele encodes a non-functional glycosyltransferase and is characterized by a single base pair deletion at base pair 261, resulting in the loss of enzyme translation and unmodified H antigen.^{18,19} Thus, the carbohydrate moieties present on the surface of the erythrocyte's membrane define ABO blood group antigens.²⁰ Besides red blood cells, the expression of ABO antigens is also observed on the surface of various human cells and tissues, such as vascular endothelium, platelets, sensory neurons, mucus secretions, and epithelial tissues.²¹

1.1.2. Immune response

Blood group antigens are considered primarily tissue antigens distributed throughout the body. The rejection of transplanted organs and natural abortions is caused by antibodies produced against these antigens.²² ABO antigens expressed in normal tissues have been reported to be different from those expressed in cancerous cells.^{23,24} This difference is assumed to alter cell motility, apoptosis, and immune escape.²⁵ The ABO blood type system is linked to several diseases including cancer in humans based on the presence or absence of those antigens throughout the body.^{26,27} However, the underlying phenomena associated with the risk of ABO variants with tumor development and progression remain unclear and have become the subject of research.

A possible assumption is that malignancy is induced by the dysregulation of the enzymatic activity of ABO glycosyltransferases that play major roles in intercellular adhesion, cell membrane signaling, and host immune response.²⁸⁻³¹ This mechanism is similar to the process by which ABO glycosyltransferases regulate circulating plasma levels of von Willebrand factor (Figure 2), which was recently discovered as an important regulator of angiogenesis and apoptosis in tumorigenesis.³²⁻³⁴ Alternation in the host inflammatory system and systemic inflammatory response may also influence blood group

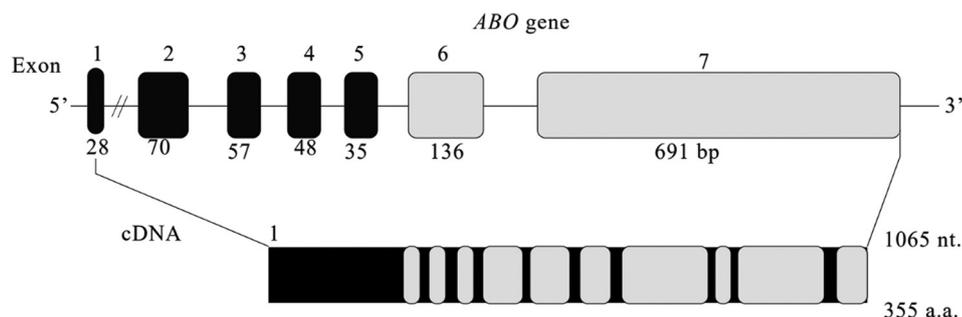


Figure 1. Structure of the ABO gene locus showing the nucleotide sequences of the A, B, and O alleles¹⁷
Abbreviations: a.a., amino acid; bp, base pair; nt, nucleotide position.

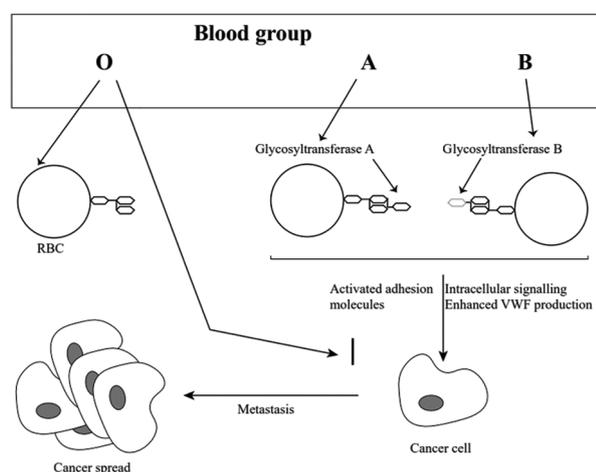


Figure 2. Association between ABO antigens and cancer⁸
Abbreviation: VWF, von Willebrand factor.

antigens to promote the spread and progression of malignancy.^{35,36} In addition, glycosylation can direct conformational changes in proteins such as epidermal growth factor receptors or alter the immune surveillance ability of immune cells such as natural killer cells that promote malignancy.³⁷

1.1.3. Adhesion molecules

Similarly, the relationship between ABO variants and circulating levels of adhesion molecules (intercellular adhesion molecule-1 [ICAM-1], E-selectin, and P-selectin) has provided a background that supports the influence of ABO in tumorigenesis, as these molecules are pivotal regulators during chronic inflammation and recruitment of immune cells.⁸ A reduced level of ICAM-1 in patients with the non-O blood group (specifically the A blood group) than in those with the O blood group is assumed to promote metastasis that causes a decrease in survival in patients with cancer and non-O group and favors prognosis in patients with the blood group O.³⁸⁻⁴³ Because the blood group polysaccharides expressed on the cell surface of metastatic cancer cells function as cell adhesion molecules, a correlation was found between blood group antigen expression in tumors and metastasis and prognosis for various malignancies, including colon, breast, and prostate cancer.⁴⁴

2. Methodology

Google Scholar, PubMed, Research 4 Life, and Web of Science were systematically searched to identify relevant research papers published before January 2023. The search strategy was designed to capture peer-reviewed articles and comprehensive reviews that investigated the relationship between the ABO blood group and the risk of developing common cancers. Specific search terms

included combinations of keywords such as “ABO blood group,” “cancer risk,” “oncology,” and specific cancer types (e.g., breast, colorectal, lung, and prostate cancer).

Studies that provided original data or meta-analyses linking ABO blood group phenotypes with cancer incidence or susceptibility were included, particularly those presenting significant findings, large sample sizes, or critical insights into the potential mechanisms underlying this association. Studies unrelated to cancer or those that lacked clear ABO blood group data were excluded. Each article was reviewed for quality, relevance, and methodological rigor. Special attention was given to studies that controlled for confounding variables such as age, sex, lifestyle factors, and comorbidities. The results of the selected studies were analyzed thoroughly to assess the strength of the evidence connecting the ABO blood group with cancer risk and to identify patterns or inconsistencies across different types of cancer. This methodology allowed for a comprehensive evaluation of the current understanding of the role of the ABO blood group in cancer development.

3. Some major cancers associated with the ABO blood group

Association of different blood types and its association with the development of different cancers are shown in Table 1.

3.1. Gastric cancer

Gastric cancer comprises 7% of all cancers globally. Studies have shown a stronger association between A and AB blood groups and gastric cancers. For example, the A blood group showed an odds ratio (OR) of 1.13 and a 95% confidence interval (CI) of 1.02 – 1.24, and the AB blood group shared an OR of 1.18 and a 95% CI of 1.02 – 1.36.⁴⁵ These ORs indicate a positive association between the A and AB blood groups and the risk of gastric cancer, with these groups having slightly higher odds of developing the disease. The CIs for both blood groups were narrow and >1, meaning that the associations were statistically significant and not likely due to random variations. Recently, the Chi-squared value ($\chi^2 = 4.708$, $P < 0.001$) reported by Yu *et al.*⁴⁶ demonstrated a significant relationship between the A blood group and gastric cancer development. Similarly, Rummel and Ellsworth found that the A blood group exhibited a greater risk of gastric cancer.¹⁷ The specific blood type antigen (e.g., Lewis-b antigen), the result of blood type genes at 19q13, was found to mediate the attachment of *Helicobacter pylori* to the human gastric mucosa, a causative agent in chronic active gastritis, in a study on the association between the ABO blood group and gastric cancer.^{47,48}

Table 1. Different types of human cancers associated with the ABO blood group

Types of cancer	Association with the ABO blood group	References
Gastric	An increased risk of gastric cancer was observed among individuals with blood group A (incidence rate ratio = 1.20, 95% confidence interval [CI] 1.02 – 1.42)	124
	The risk of gastric cancer was significantly higher in A blood group than in the non-A groups (O, B, and AB) (odds ratio [OR] 1.34; 95% 1.25 – 1.44).	47
	Blood groups A and AB were found to be associated with gastric cancer: Group A, OR 1.13, 95% CI 1.02 – 1.24; group AB, OR1.18, 95% CI 1.02 – 1.36.	45
	The frequency distribution of patients gastric cancer having the A blood group was significantly increased ($\chi^2=4.708, P<0.001$), while the frequency distribution patients with gastric cancer having the AB blood group was significantly decreased ($\chi^2=9.630, P<0.01$).	46
Pancreatic	Increased risk in blood type A compared with its frequency among regional blood donors (47.63% vs. 39.10%, OR 1.43, $P<0.01$)	52
	Compared with the OO genotype, those with the AO and AA genotypes had ORs of 1.67 (95% CI 1.08 – 2.57) and 1.53 (95% CI 0.80 – 2.91), respectively, whereas individuals with the BO and BB genotypes had ORs of 1.24 (95% CI 0.74 – 2.06) and 3.28 (95% CI 1.38 – 7.80), respectively.	51
	Increased risk in the group with A blood group compared with the control group (OR 1.8, 95% CI (NA), $P<0.01$). A lower rate of risk in the group with AB blood group than in the control group (OR, 0.37; 95% CI (NA), $P<0.01$).	54
	Non-O groups were linked to a higher incidence of pancreatic cancer. Elevated risk found across all non-O blood types (type A, HR 1.45; type B, HR 1.59; and type AB, HR 1.37).	49
	Increased cancer risk of blood type A with the estimated adjusted odds ratios (AORs with 95% confidence intervals [CIs]) of 2.130 (1.409 – 3.220)	55
	Increased risk found in type A compared with the non-O type (HR 0.719, 95% CI 0.521 – 0.974, $P<0.01$)	50
Breast	Higher incidence of blood group A (OR 2.13, 95% CI 1.04 – 2.96, $P<0.01$).	63
	Blood group A was at higher risk (OR 7.444, 95% CI 4.098 – 13.5222).	60
	Blood group A showed a higher incidence of breast cancer (45.88%), whereas a lower incidence was observed in blood group AB (6.27%).	65
	No association was observed.	47,66,67
Prostatic	The non-O blood group was at higher risk than the O group (high-risk percentage: O vs. non-O: 72.5% vs. 85.7%, $P<0.01$)	47
	Blood group B demonstrated an increased risk of cancer (OR 1.23, $P<0.05$).	91
	No significant association was observed.	62
	No significant association was observed ($P>0.05$)	64
Colorectal	No significant association was observed between any blood group and colorectal cancer (P interaction = 0.91)	84
	Non-AB blood type was found to be at greater risk with HRs for patients of with A, B, and O of 4.37 (95% CI, 2.65 – 7.20), 2.99 (95% CI 1.81 – 4.96), and 2.78 (95% CI 1.69 – 4.56), respectively, compared with AB blood type.	81
	No significant association was observed ($P>0.05$).	125
	No significant association was found.	49
	Individuals with blood type A had a borderline significant higher risk of colorectal cancer (HR 1.18, 95% CI 0.97 – 1.43, $P=0.097$) than those with blood type O.	47
Kidney	The non-O type was associated with decreased overall survival (HR 1.68, 95% CI 1.18 – 2.39, $P<0.01$).	38
	No significant association was reported.	26,101,102
Urinary bladder	Blood type O had worse recurrence and progression rates than type A ($P=0.015$ and 0.031) or B ($P<0.01$ and 0.075).	107
	Blood type B demonstrated significantly higher risk (OR 1.26, $P<0.01$)	91
Ovarian	Women with blood type A had a greater incidence of ovarian cancer. The incidence ratio was 1:17.	126
	The incidence of ovarian cancer with the B antigen was higher, whereas the A antigen did not share an increasing risk of ovarian cancer.	71

(Cont'd...)

Table 1. (Continued)

Types of cancer	Association with the ABO blood group	References
	The A blood group shared an increased risk of ovarian cancer: (OR 1.09, 95% CI 1.01 – 1.18; $P < 0.01$). As per the diplotype analysis, type AO was more linked with increased risk than AA (AO, OR 1.11, 95% CI 1.01 – 1.22, $P < 0.01$; AA, OR 1.03, 95% CI 0.87 – 1.21, $P > 0.05$). The other diplotype AB and B blood groups had no significant ovarian cancer risk.	108
	A and B antigens shared an increasing risk of ovarian cancer. However, the B blood group (OR 1.48, 95% CI 1.17 – 1.81, $P < 0.01$) shared a higher risk of ovarian cancer than the A blood group (OR 1.40; 95% CI 1.13 – 1.73, $P = 0.0019$).	109
Cervical	Higher incidence of cervical cancer in patients with the A blood group.	26,114,115
	Higher incidence of cervical cancer (37.9%) in patients with the B blood group.	127
	No significant correlation was observed.	110,111,128,129
Nasopharyngeal	Individuals with blood types A and AB had a higher risk of NPC than those with blood type O.	119
	No significant association was observed between any blood group and NPC.	118
	No significant difference was obtained between patients with the O and non-O blood groups, except for the significantly lower distant metastasis-free survival (DMFS) in patients with the O blood group. The O blood type was associated with an unfavorable DMFS in female patients with NPC.	47
Lung	No significant association was observed between any blood group and non-small-cell lung cancer.	121
	Increased risk of lung cancer in patients with non-O blood type and Rh negative.	62
	Higher risk of lung cancer in those with blood type AB than in those with blood types B and O.	47
Skin	The risks of developing SCC and BCC in participants with the non-O blood group were 14% and 4%, respectively. No significant linkage was observed between the blood type and melanoma.	122
	A significant association was found between patients with BCC and controls in terms of A Rh (-) ($P < 0.01$).	123

Note: NA: Not available.

Abbreviations: HR: Hazard ratio; NPC: Nasopharyngeal carcinoma; DMFS: Distant-metastasis-free survival; SCC: Squamous cell carcinoma; BCC: Basal cell carcinoma.

3.2. Pancreatic cancer (PC)

PC is one of the most common cancers and the leading cause of death from cancer worldwide. An overall significant increased risk for PC was found in a Taiwanese cohort study involving 339,432 participants with non-O blood type (hazard ratio [HR] = 1.50, 95% CI 1.04 – 2.19).⁴⁹ In a recent comparative study of long-term outcomes of 406 patients with PC between A alleles and non-A alleles according to treatments (resection, $P < 0.05$; chemotherapy, $P = 0.757$; and palliative care, $P = 0.532$), patients with A alleles who underwent resection possessed a greater risk than those with non-A alleles.⁵⁰ In a case-control study conducted on 185 patients/1465 controls in the Japanese population, those with the A blood group were at a greater risk of PC than individuals with the O blood group.⁵¹ In the study by Greer *et al.*, 274 patients also showed a greater risk for those with the A blood group.^{52,53} Another study conducted in the Turkish population among 132 patients/633 controls by Engin *et al.* and in China among 264 patients/687 controls by Li *et al.* also confirmed the increased rate of the risk of the A blood group.^{54,55} Therefore, these studies show a possible association between the ABO blood group and the PC risk, with a greater risk for those with the A blood group.⁵⁶

3.3. Breast cancer

Breast cancer is one of the most common cancers in women. According to the Breast Cancer Research Foundation, nearly two million new cases of breast cancer were diagnosed in 2018. Globally, approximately 12% of newly diagnosed cancer is caused by breast cancer.⁵⁷⁻⁵⁹ Saxena *et al.* reported the maximum occurrence of breast carcinoma in the A blood group and a minimum in the AB blood group. Patients with the A blood group (OR 7.444, 95% CI 4.098 – 13.5222) were observed at higher risk than those with blood group AB (OR 1, 95% CI 0.476 – 2.103) when taking reference to the proportion of breast cancer in the AB blood group.⁶⁰ However, no association between the blood group and the risk of breast cancer was observed in a study of 368 patients with cancer in Bhopal, India.⁶¹ Similarly, no relationship was observed between the HER2 status and ABO blood group examined in 294 Turkish female patients with HER2 (+) breast cancer.⁶² A study of 160 women with breast cancer during their pre-operative control and follow-up, following mastectomy, in Mansoura University Hospital, Egypt, revealed a higher frequency of breast cancer in those with the A blood group (OR 2.13, 95% CI 1.04 – 2.96, $P < 0.05$) and lower cancer frequency in those with the AB blood group (OR 0.74,

95% CI 0.30 – 1.84, $P = 0.52$) compared with the control participants.⁶³ However, Flavarjani *et al.* did not find a significant association between blood types and breast cancer ($P > 0.05$) in a study of 549 women including 173 cases and 376 controls.⁶⁴ In the study by Meo *et al.*,⁶⁵ the incidence of breast cancer was higher in patients with the A blood group (45.88%) than in those with the AB blood group (6.27%).⁶⁵ Some studies have not found a relationship between the ABO blood group and breast cancer risk or survival.^{66,67}

A meta-analysis of 14 studies conducted by Miao *et al.* did not find an association between the ABO blood group and breast cancer risk but reported that Caucasian people with the A blood group might be at higher risk for this cancer.⁶⁸ Two studies observed a significant association of blood type A with a higher risk of breast cancer.^{69,70} In contrast, no association was found between the ABO blood group and the risk or survival or mortality of invasive, ductal, or hormone receptor-positive breast cancers.^{71,72} Yu *et al.* did not observe an association between the ABO blood group and triple-negative breast cancer.⁷³ However, Amini *et al.* observed a significant association between the tumor size and axillary lymph node involvement and the ABO blood group.⁷⁴ A study reported a positive relationship between the risk of breast cancer and the O blood group.⁷⁵ Some studies have suggested that people with blood types B and AB have a significantly increased risk of breast cancer with a poorer overall survival (OS) than those with A and O blood groups.^{76,77} Stamatakos *et al.* reported the association of the A antigen with the increased incidence of invasive ductal carcinoma in 166 Greek women.⁷⁸ Tryggvadottir *et al.*⁷⁹ observed a twofold higher incidence of familial breast cancer in those with the B blood group while studying bilateral breast cancer in familial and sporadic cases of the ABO blood group.⁷⁹ In addition, Anderson and Haas showed a positive association between A and B blood groups in women with a family history of breast cancer.⁸⁰

3.4. Colorectal cancer

In comparison with gastric cancer and PC, very few studies have examined the correlation between the ABO blood group and colorectal cancer development. In a study conducted from 1995 to 2002, among 1555 patients, a greater risk was noted in those with the non-AB blood group.⁸¹ In the multivariate analysis, a modest association of the B blood group (HR 1.20, 95% CI 1.00 – 1.45) with colon cancer was observed compared with the O blood group.^{82,83} However, in the studies conducted by Khalili *et al.* among 1025 patients and by Li *et al.* among 1314 patients, no significant association was observed between any blood group and colorectal cancer.⁸⁴⁻⁸⁶ In the Shanghai Cohort Study 1986 – 2013 with 624 patients and

355,797 controls, individuals with the A blood group had a borderline significant higher risk of colorectal cancer (HR 1.18, 95% CI 0.97 – 1.43, $P = 0.097$) than those with the O blood group.⁴⁷ Most studies did not show a significant association between the blood group and colorectal cancer. However, some studies have suggested the increased risk of colorectal cancer in the non-AB blood group, and those with the A blood group had a higher risk. In addition, the O blood group was the most prevalent ABO blood group among patients with type I endometrial cancer (EC) and was associated with an increased risk of developing type I EC. However, the ABO blood group was not significantly correlated with the stage or differentiation of type I EC.⁸⁷ Patients with hepatocellular carcinoma who have the A blood group may have lower OS and recurrence-free survival rates following hepatectomy compared with those with non-A blood groups.⁸⁸

3.5. Prostate cancer

Prostate cancer accounts for approximately 8% of the global cancer incidence.^{58,89} Few studies have reported to date the association between ABO blood groups and prostate cancer. Wang *et al.* demonstrated that the patients with the O blood group have a lower risk of prostate cancer and are less aggressive than non-O blood groups (high-risk percentage: O vs. non-O: 72.5% vs. 85.7%, $P < 0.05$) and suggested that nearly all of the included studies compared patients with prostate cancer with the normal population without revealing an association between the ABO blood groups and the risk of invasiveness in patients with prostate cancer.⁹⁰ In a previous study, the B blood group was found to be significantly more frequent in patients with prostate cancer, suggesting that patients with the B blood group were at an increased risk of cancer (OR 1.23, $P < 0.05$).⁹¹ Some studies have not found a relationship between the blood type and prostate cancer risk or survival.^{17,47,92-94} A study reported that tumor progression is favored by the loss of antigen expression at the tissue level.⁹⁵ However, other studies have suggested that prostate tissue without antigen expression cannot be considered a biomarker of invasion.⁹⁶ The loss of blood group A antigen and retention of the H antigens were observed in tumor tissues of the prostate.⁹⁷ With tumor progression, the expression of the A antigen has been reported to decrease, which might be associated with the increased risk of biochemical recurrence of prostate cancer in patients with the A blood group.^{98,99}

3.6. Kidney and urinary bladder cancer

The expression of ABO antigens is observed on the surface of several normal and cancerous tissues, including kidneys and renal cell carcinoma lines.¹⁰⁰ Several studies have examined the association of the ABO blood group with renal cell carcinoma. A study of 900 patients undergoing surgery

for locoregional renal carcinoma reported an association between the ABO blood group (non-O) and OS, indicating the non-O blood group as an independent biomarker of mortality. The study found that the non-O blood group was associated with decreased OS in the multivariate analysis (HR 1.68, 95% CI 1.18 – 2.39, $P < 0.05$).³⁸ Another study observed that the absence of lymph node metastasis had no suitable effect on the prognosis in patients with the O blood group and found no association between the ABO blood group and survival outcomes.^{101,102} Stakišaitis *et al.* did not find any significant relationship between the ABO blood group and kidney cancer survival.⁹¹ While some researchers have identified the ABO blood group as a prognostic predictor, others did not find any association with renal cancer.²⁰ One study reported no significant association between the ABO blood group and kidney cancer,²⁶ whereas a cohort study found a higher occurrence of renal cell carcinoma in women with the non-O blood group compared to those with the O blood group.¹⁰³

The prevalence of the A blood group was higher in patients with bladder cancer.¹⁰⁴ In a study of the Lithuanian population, the B blood group was found to be significantly more frequent in people with bladder cancer compared to the control group of blood donors. The B blood group was more common in men (OR 1.27, $P < 0.05$); however, no association was found in women with bladder cancer ($P > 0.05$).¹⁰⁵ Another study found that the B blood group was significantly associated with bladder cancer risk (OR 1.26, $P < 0.05$), whereas no significant association was observed with the O blood group (OR 0.76, $P < 0.05$).⁹¹ Another study suggested that patients with the O blood group exhibited more aggressive tumor behavior in bladder cancer, with higher tumor grade and more relapses than those with the A blood group.¹⁰⁶ Similarly, another study showed that the O blood group was associated with worse recurrence and progression rates compared to the A ($P = 0.015$ and 0.031) or B ($P = 0.004$ and 0.075) blood groups.¹⁰⁷

3.7. Ovarian cancer

Ovarian cancer is the seventh leading cause of death among women globally.⁸⁹ It is also linked with certain ABO blood groups.^{71,97,108,109} Two studies concluded that carriage of A and B antigens in the ABO blood group increased the risk for ovarian cancer, with the B blood group showing a higher risk.⁷¹ In contrast, another study¹⁰⁸ reported that women with the A blood group were more susceptible to ovarian cancer (OR 1.09, 95% CI 1.01 – 1.18; $P < 0.05$). Similarly, a haplotype analysis revealed that the AO blood group carried a higher risk than the AA blood group.¹⁰⁸ Another study reported a higher risk of ovarian cancer in individuals with the A blood group, with 1 in 17 women affected.⁷¹

3.8. Cervical cancer

Cervical cancer is a common cancer in women, representing 4% of the global cancer incidence^{58,89} Several studies have reported no significant correlation between the ABO blood group and cervical cancer.¹⁰⁹⁻¹¹² However, a higher incidence of cervical cancer (37.9%) was observed in patients with the B blood group.¹¹³ In a group of Japanese women, most of the women with the A blood group had cervical cancer.¹¹⁴ A similar result was observed in a study conducted in India.¹¹⁵ The incidence of cervical cancer was higher in women with the A blood group than in those with the O blood group.¹⁵ However, no association was found between the blood group and the risk of cervical cancer in studies conducted in Nigeria or southeast Siberia.^{109,116} In addition, the RhD factor may influence OS in cervical cancer, but current data lack strong significance. Larger studies are needed to confirm its role and explore the impact of blood groups on female cancers.¹¹⁷

3.9. Nasopharyngeal carcinoma (NPC)

A study of 2439 patients with NPC from 2001 to 2004 showed no significant difference between patients with O and non-O blood groups, except for a significantly shorter distant-metastasis-free survival (DMFS) in patients with the O blood group (aHR = 1.2268, 95% CI 1.010 – 1.592, $P < 0.05$). In female patients, those with the O blood group had significantly shorter OS ($P < 0.05$) and DMFS ($P < 0.05$) than those with the non-O blood group. However, in male patients, no significant differences were observed ($P > 0.05$).⁹⁰ Similarly, Lin *et al.*¹¹⁸ did not find a significant difference in the distribution of ABO blood groups between the NPC and control groups ($P = 0.884$). However, a significant difference between the sexes and ABO blood groups was observed, except for the AB blood type ($P = 0.246$).¹¹⁸ In contrast, another study found an association between the ABO blood group and NPC risk. The medical data of 1,538 patients with NPC from 2004 to 2011 showed that A and AB blood types were associated ($P < 0.05$ and $P < 0.05$) with an increased risk of NPC when compared with the O blood group. The distant metastasis rate was significantly higher among men with the A blood group than in those with the non-A blood groups ($P < 0.05$).¹¹⁹ Thus, the correlation between the ABO blood group and NPC remains controversial.

3.10. Lung cancer

In a study conducted among 964 patients with lung cancer in China, those with the AB blood type showed a relatively higher risk of lung cancer (HR 1.01, 95% CI 0.81 – 1.26) than those with the A blood group A.⁴⁷ Another study conducted on 417 Turkish patients by Urun *et al.* confirmed the association between the ABO blood group and lung

cancer, wherein the non-O blood group (OR 0.864, 95% CI 0.787 – 0.950) was associated with an increased risk of lung cancer compared with the O blood group.¹²⁰ In contrast, a study involving 81 patients found no significant effect of the ABO blood group on the prognosis of non-small-cell lung cancer.¹²¹

3.11. Skin cancer

A study conducted from 1996 to 2006 explored the potential association between the ABO blood group and melanoma, squamous cell carcinoma (SCC), and basal cell carcinoma (BCC). The multivariable HRs for the non-O blood groups (A, B, and AB) were 0.91 (95% CI 0.78 – 1.05), 0.86 (95% CI 0.78 – 0.95), and 0.96 (95% CI 0.93 – 0.99) for melanoma, SCC, and BCC, respectively. This suggested a lower risk of developing SCC in participants with the non-O blood group than in those with the O blood group.¹²² A study conducted from 2005 to 2012 among 255 patients with skin cancer showed no significant difference in the distribution of O and A blood groups between the SCC and BCC groups ($P = 0.663$).¹²³ Overall, the results suggest an association between the non-O blood group and a higher risk of non-melanoma skin cancer.

4. Conclusion

The association between blood group and cancer risk was significant only in pancreatic and gastric cancer, with individuals possessing the A blood group being at greater risk. However, results were inconsistent in studies conducted on other types of cancer. This study provides baseline data for understanding the association of blood type with the risk of cancer development.

Further prospective studies with larger patient populations are recommended to better understand the significance of the ABO blood group as a predictive factor in different cancer types. Most recent discoveries have focused on ABO phenotype, making studies on the ABO genotype crucial for identifying new therapeutic targets. Owing to the limited research in this area in Nepal, Nepalese researchers should be encouraged to conduct studies exploring the association between the ABO blood group and cancer risk in the Nepalese population.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

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Ethics approval and consent to participate

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References

1. Di Meo S, Iossa S, Venditti P. Skeletal muscle insulin resistance: Role of mitochondria and other ROS sources. *J Endocrinol.* 2017;233(1):R15-R42.
doi: 10.1530/JOE-16-0598
2. Liunbruno GM, Franchini M. Hemostasis, cancer, and ABO blood group: The most recent evidence of association. *J Thromb Thrombolysis.* 2014;38(2):160-166.
doi: 10.1007/s11239-013-1027-4
3. Siransy LK, Nanga ZY, Zaba FS, Tufa NY, Dasse SR. ABO/Rh blood groups and risk of HIV infection and hepatitis B among blood donors of Abidjan, Côte D'ivoire. *Eur J Microbiol Immunol.* 2015;5(3):205-209.
doi: 10.1556/1886.2015.00029
4. Beauchemin N, Arabzadeh A. Carcinoembryonic antigen-related cell adhesion molecules (CEACAMs) in cancer progression and metastasis. *Cancer Metastasis Rev.* 2013;32(3-4):643-671.
doi: 10.1007/s10555-013-9444-6
5. Pasko BE, Abbott D, Bocsi GT, Draper NL. ABO blood groups are not associated with COVID-19 disease incidence and severity when correcting for ethnicity differences in blood type. *Am J Clin Pathol.* 2022;158(2):249-253.
doi: 10.1093/ajcp/aqac036
6. Ewald DR, Sumner SCJ. Blood type biochemistry and human disease. *Wiley Interdiscip Rev Syst Biol Med.* 2016;8(6):517-535.
doi: 10.1002/wsbm.1355
7. Ogasawara K, Sano R, Kominato Y. Review of ABO expression and variations based on transcriptional regulation of the ABO blood group gene. *Transfus Med Hemother.* 2024;51(4):210-224.
doi: 10.1159/000536556
8. Franchini M, Liunbruno GM, Lippi G. The prognostic value

- of ABO blood group in cancer patients. *Blood Transfus.* 2016;14(5):434-440.
doi: 10.2450/2015.0164-15
9. Aird I, Bentall HH, Roberts JA. A relationship between cancer of stomach and the ABO blood groups. *Br Med J.* 1953;1(4814):799-801.
doi:10.1136/bmj.1.4814.799
10. Shvartsur A, Bonavida B. Trop2 and its overexpression in cancers: Regulation and clinical/therapeutic implications. *Genes Cancer.* 2015;6(3-4):84-105.
doi: 10.18632/genesandcancer.40
11. Reid ME, Bird GW. Associations between human red cell blood group antigens and disease. *Transfus Med Rev.* 1990;4(1):47-55.
doi: 10.1016/s0887-7963(90)70247-7
12. Benvenuto M, Focaccetti C, Izzi V, Masuelli L, Modesti A, Bei R. Tumor antigens heterogeneity and immune response-targeting neoantigens in breast cancer. *Semin Cancer Biol.* 2021;72:65-75.
doi: 10.1016/j.semcancer.2019.10.023
13. Hu B, Zhang H, Zhang Y, Jin Y. A nomogram based on biparametric magnetic resonance imaging for detection of clinically significant prostate cancer in biopsy-naïve patients. *Cancer Imaging.* 2023;23(1):82.
doi: 10.1186/s40644-023-00606-2
14. Müller V, Hein A, Hartkopf AD, et al. Occurrence and characteristics of patients with *de novo* advanced breast cancer according to patient and tumor characteristics - A retrospective analysis of a real world registry. *Eur J Cancer.* 2022;172:13-21.
doi: 10.1016/j.ejca.2022.05.015
15. Garratty G. Blood groups and disease: A historical perspective. *Transfus Med Rev.* 2000;14(4):291-301.
doi: 10.1053/tmrv.2000.16228
16. Ghafel N. Association of the blood groups with mostly public diseases. *Kufa Jour Nurs Sci.* 2021;11(1):1-17.
doi: 10.36321/kjns.vi20211.471
17. Rummel SK, Ellsworth RE. The role of the histoblood ABO group in cancer. *Future Sci OA.* 2016;2(2):FSO107.
doi: 10.4155/fsoa-2015-0012
18. Ah-Moye D, Davies C, Goody J, Hayward P, Frewin R. Introduction to haematology and transfusion science. In: *Clinical Biochemistry: Metabolic and Clinical Aspects.* United Kingdom: Churchill Livingstone; 2014. p. 497-514.
doi:10.1016/B978-0-7020-5140-1.00026-2
19. Franchini M, Liumbruno GM. ABO blood group: Old dogma, new perspectives. *Clin Chem Lab Med.* 2013;51(8):1545-1553.
doi: 10.1515/cclm-2013-0168
20. Franchini M, Crestani S, Frattini F, Sissa C, Bonfanti C. ABO blood group and von Willebrand factor: Biological implications. *Clin Chem Lab Med.* 2014;52(9):1273-1276.
doi: 10.1515/cclm-2014-0564
21. Eastlund T. The histo-blood group ABO system and tissue transplantation. *Transfusion.* 1998;38(10):975-988.
doi: 10.1046/j.1537-2995.1998.381098440863.x
22. Yamamoto F, Cid E, Yamamoto M, Blancher A. ABO research in the modern era of genomics. *Transfus Med Rev.* 2012;26(2):103-118.
doi: 10.1016/j.tmr.2011.08.002
23. Strauchen JA, Bergman SM, Hanson TA. Expression of A and B tissue isoantigens in benign and malignant lesions of the breast. *Cancer.* 1980;45(8):2149-2155.
doi: 10.1002/1097-0142(19800415)45:8<2149:aid-cnrc2820450823>3.0.co;2-7
24. Chen PH, Bossuyt V, Reisenbichler E. Expression of lymphoid enhancer-binding factor 1 in breast fibroepithelial lesions. *Hum Pathol.* 2021;108:68-75.
doi: 10.1016/j.humpath.2020.11.009
25. Li D, Wang M, Qi J, et al. Human group A rotavirus P [25 VP8* specifically binds to A-type histo-blood group antigen. *Virology.* 2021;555:56-63.
doi: 10.1016/j.virol.2020.12.016
26. Garratty G, Glynn SA, McEntire R. Retrovirus epidemiology donor study. ABO and Rh(D) phenotype frequencies of different racial/ethnic groups in the United States. *Transfusion.* 2004;44(5):703-706.
doi: 10.1111/j.1537-2995.2004.03338.x
27. Castillo B, Dasgupta A, Klein K, Tint H, Wahed A. *Transfusion Medicine for Pathologists: A Comprehensive Review for Board Preparation, Certification, and Clinical Practice.* United States: Academic Press; 2018.
doi:10.1016/B978-0-12-814313-1.00013-7
28. Hakomori S. Tumor-associated carbohydrate antigens defining tumor malignancy: Basis for development of anti-cancer vaccines. *Adv Exp Med Biol.* 2001;491:369-402.
doi: 10.1007/978-1-4615-1267-7_24
29. Hakomori S. Antigen structure and genetic basis of histo-blood groups A, B and O: Their changes associated with human cancer. *Biochim Biophys Acta.* 1999;1473(1):247-266.
doi: 10.1016/s0304-4165(99)00183-x
30. Roseman S. Reflections on glycobiology. *J Biol Chem.* 2001;276(45):41527-41542.
doi: 10.1074/jbc.R100053200

31. Zhang S, Zhang HS, Cordon-Cardo C, *et al.* Selection of tumor antigens as targets for immune attack using immunohistochemistry: II. Blood group-related antigens. *Int J Cancer*. 1997;73(1):50-56.
doi: 10.1002/(sici)1097-0215(19970926)73:1<50:aid-ijc9>3.0.co;2-0
32. Capuzzo E, Bonfanti C, Frattini F, *et al.* The relationship between ABO blood group and cardiovascular disease: Results from the Cardiorisk program. *Ann Transl Med*. 2016;4(10):189.
doi: 10.21037/atm.2016.03.58
33. Franchini M, Frattini F, Crestani S, Bonfanti C, Lippi G. von Willebrand factor and cancer: A renewed interest. *Thromb Res*. 2013;131(4):290-292.
doi: 10.1016/j.thromres.2013.01.015
34. Jenkins PV, O'Donnell JS. ABO blood group determines plasma von Willebrand factor levels: A biologic function after all? *Transfusion*. 2006;46(10):1836-1844.
doi: 10.1111/j.1537-2995.2006.00975.x
35. Grivennikov SI, Greten FR, Karin M. Immunity, inflammation, and cancer. *Cell*. 2010;140(6):883-899.
doi: 10.1016/j.cell.2010.01.025
36. Melzer D, Perry JRB, Hernandez D, *et al.* A genome-wide association study identifies protein quantitative trait loci (pQTLs). *PLoS Genet*. 2008;4(5):e1000072.
doi: 10.1371/journal.pgen.1000072
37. Greenwell P. Blood group antigens: Molecules seeking a function? *Glycoconj J*. 1997;14(2):159-173.
doi: 10.1023/a:1018581503164
38. Kaffenberger SD, Morgan TM, Stratton KL, *et al.* ABO blood group is a predictor of survival in patients undergoing surgery for renal cell carcinoma. *BJU Int*. 2012;110(11 Pt B):E641-E646.
doi: 10.1111/j.1464-410X.2012.11366.x
39. Eibl G, Edderkaoui M. *Risk Factors for Pancreatic Cancer: Underlying Mechanisms and Potential Targets*. Switzerland: Frontiers Media; 2015.
doi: 10.3389/fphys.2014.00490
40. Neoptolemos JP, Urrutia RA, Abbruzzese J, Büchler MW. *Pancreatic Cancer*. Germany: Springer Science and Business Media; 2010.
doi:10.1007/978-1-4939-7193-0
41. Bahia D, Satoskar A, Dussurget O. *Cell Signaling in Host-Pathogen Interactions: The Host Point of View*. Switzerland: Frontiers Media; 2018.
doi:10.3389/fimmu.2018.00221
42. Zusso M, Moro S, Giusti P, Stokes L. *Neuroinflammation and Its Resolution: From Molecular Mechanisms to Therapeutic Perspectives*. Switzerland: Frontiers Media; 2020.
doi:10.3389/fphar.2020.00480
43. Bronte F, Manu KA, Giunta EF. *Reviews in Gastrointestinal Cancers*. Switzerland: Frontiers Media; 2023.
doi:10.3389/fonc.2023.1252665
44. Shad KF. *Blood Groups: More than Inheritance of Antigenic Substances*. Germany: BoD – Books on Demand; 2022.
doi: 10.5772/intechopen.94700
45. Mao Y, Yang W, Qi Q, *et al.* Blood groups A and AB are associated with increased gastric cancer risk: Evidence from a large genetic study and systematic review. *BMC Cancer*. 2019;19(1):164.
doi: 10.1186/s12885-019-5355-4
46. Yu H, Xu N, Li ZK, *et al.* Association of ABO blood groups and risk of gastric cancer. *Scand J Surg*. 2020;109(4):309-313.
doi: 10.1177/1457496919863886
47. Huang JY, Wang R, Gao YT, Yuan JM. ABO blood type and the risk of cancer - Findings from the Shanghai Cohort Study. *PLoS One*. 2017;12(9):e0184295.
doi: 10.1371/journal.pone.0184295
48. Liu Y, Chen S, Shen W, Qu X, Li S, Shi Y. Construction and validation of a gastric cancer diagnostic model based on blood groups and tumor markers. *J Cancer*. 2024;15(3):729-736.
doi: 10.7150/jca.88190
49. Sun W, Wen CP, Lin J, *et al.* ABO blood types and cancer risk--a cohort study of 339,432 subjects in Taiwan. *Cancer Epidemiol*. 2015;39(2):150-156.
doi: 10.1016/j.canep.2014.12.006
50. Tanaka Y, Kumagi T, Terao T, *et al.* ABO blood type and the long-term outcomes of pancreatic cancer. *Intern Med*. 2020;59(6):761-768.
doi: 10.2169/internalmedicine.3748-19
51. Nakao M, Matsuo K, Hosono S, *et al.* ABO blood group alleles and the risk of pancreatic cancer in a Japanese population. *Cancer Sci*. 2011;102(5):1076-1080.
doi: 10.1111/j.1349-7006.2011.01907.x
52. Greer JB, Yazer MH, Raval JS, Barmada MM, Brand RE, Whitcomb DC. Significant association between ABO blood group and pancreatic cancer. *World J Gastroenterol*. 2010;16(44):5588-5591.
doi: 10.3748/wjg.v16.i44.5588
53. Védie AL, Laouali N, Gelot A, Severi G, Boutron-Ruault MC, Rebours V. Childhood and adulthood passive and active smoking, and the ABO group as risk factors for pancreatic cancer in women. *United Eur Gastroenterol J*. 2024;12(4):440-450.
doi: 10.1002/ueg2.12487

54. Engin H, Bilir C, Üstün H, Gökmen A. ABO blood group and risk of pancreatic cancer in a Turkish population in Western Blacksea region. *Asian Pac J Cancer Prev*. 2012;13(1):131-133.
55. Li X, Xu H, Gao P. ABO Blood group and diabetes mellitus influence the risk for pancreatic cancer in a population from China. *Med Sci Monit*. 2018;24:9392-9398.
doi: 10.12659/MSM.913769
56. Ateeb Z, Valente R, Pozzi-Mucelli RM, *et al*. Main pancreatic duct dilation greater than 6 mm is associated with an increased risk of high-grade dysplasia and cancer in IPMN patients. *Langenbecks Arch Surg*. 2019;404(1):31-37.
doi: 10.1007/s00423-018-1740-8
57. Gupta A, Saraiya V, Deveaux A, *et al*. Association of lipid profile biomarkers with breast cancer by molecular subtype: Analysis of the MEND study. *Sci Rep*. 2022;12(1):10631.
doi: 10.1038/s41598-022-13740-x
58. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin*. 2018;68(6):394-424.
doi: 10.3322/caac.21492
59. Lei S, Zheng R, Zhang S, *et al*. Global patterns of breast cancer incidence and mortality: A population-based cancer registry data analysis from 2000 to 2020. *Cancer Commun*. 2021;41(11):1183-1194.
doi: 10.1002/cac2.12207
60. Saxena S, Chawla VK, Gupta KK, Gaur KL. Association of ABO blood group and breast cancer in Jodhpur. *Indian J Physiol Pharmacol*. 2015;59(1):63-68.
61. Singh K, Kote S, Patthi B, *et al*. Relative risk of various head and neck cancers among different blood groups: An analytical study. *J Clin Diagn Res*. 2014;8(4):ZC25-ZC28.
doi: 10.7860/JCDR/2014/7949.4244
62. Urun Y, Utkan G, Altundag K, *et al*. ABO and Rh blood groups frequency in women with HER2 positive breast cancer. *J BUON*. 2012;17(3):457-460.
63. Aly R, Yousef A. Association of ABO blood group and risk of breast cancer. *J Blood Disord Transfus*. 2014;5(9):1000241.
doi: 10.4172/2155-9864.1000241
64. Flavarjani AH, Hedayatpour B, Bashardoost N, Nourian SM. Study of the association between blood types and breast cancer among Isfahanian women with breast cancer. *Adv Biomed Res*. 2014;3:43.
doi: 10.4103/2277-9175.125749
65. Meo SA, Suraya F, Jamil B, *et al*. Association of ABO and Rh blood groups with breast cancer. *Saudi J Biol Sci*. 2017;24(7):1609-1613.
doi: 10.1016/j.sjbs.2017.01.058
66. Dede DS, Aksoy S, Dizdar O, *et al*. Blood ABO groups and risk of breast cancer. *Med Oncol*. 2010;27(4):1433.
doi: 10.1007/s12032-009-9346-1
67. Klimant E, Glurich I, Mukesh B, Onitilo AA. Blood type, hormone receptor status, HER2/neu status, and survival in breast cancer: a retrospective study exploring relationships in a phenotypically well-defined cohort. *Clin Med Res*. 2011;9(3-4):111-118.
doi: 10.3121/cmr.2011.907
68. Miao SY, Zhou W, Chen L, Wang S, Liu XA. Influence of ABO blood group and Rhesus factor on breast cancer risk: A meta-analysis of 9665 breast cancer patients and 244,768 controls. *Asia Pac J Clin Oncol*. 2014;10(2):101-108.
doi: 10.1111/ajco.12083
69. Guleria K, Singh HP, Kaur H, Sambyal V. ABO blood groups in gastrointestinal tract (GIT) and breast carcinoma patients. *Anthropologist*. 2005;7(3):189-192.
doi: 10.1080/09720073.2005.11890905
70. Mourali N, Muenz LR, Tabbane F, Belhassen S, Bahi J, Levine PH. Epidemiologic features of rapidly progressing breast cancer in Tunisia. *Cancer*. 1980;46(12):2741-2746.
doi: 10.1002/1097-0142(19801215)46:12<2741:aid-cncr2820461234>3.0.co;2-w
71. Gates MA, Wolpin BM, Cramer DW, Hankinson SE, Tworoger SS. ABO blood group and incidence of epithelial ovarian cancer. *Int J Cancer*. 2011;128(2):482-486.
doi: 10.1002/ijc.25339
72. Zhang Y, Xu H, Pi S, Tan H, Huang B, Chen Y. The prognostic and immunological role of FKBP1A in an integrated multi-omics cancers analysis, especially lung cancer. *J Cancer Res Clin Oncol*. 2023;149:16589-16608.
doi: 10.1007/s00432-023-05362-1
73. Yu J, Gao F, Klimberg VS, Margenthaler JA. ABO blood type/Rh factor and the incidence and outcomes for patients with triple-negative breast cancer. *Ann Surg Oncol*. 2012;19(10):3159-3164.
doi: 10.1245/s10434-012-2533-x
74. Amini M, Fatah SH, Kalantari M. ABO blood groups and prognosis of breast cancer: A case-control study in Arak/Iran. *Iran J Blood Cancer*. 2012;4(2):61-65.
75. Majupuria KC, Gupta SR, Gupta LC. The study of ABO blood groups and relationship with cancer breast (a preliminary report). *Indian J Cancer*. 1966;3(3):182-183.
76. Costantini M, Fassio T, Canobbio L, Landucci M, Resasco M, Boccardo F. Role of blood groups as prognostic factors in primary breast cancer. *Oncology*. 1990;47(4):308-312.
doi: 10.1159/000226839
77. Holdsworth PJ, Thorogood J, Benson EA, Clayden AD. Blood group as a prognostic indicator in breast cancer. *Br*

- Med J.* 1985;290(6469):671-673.
doi: 10.1136/bmj.290.6469.671
78. Stamatakos M, Kontzoglou K, Safioleas P, Safioleas C, Manti C, Safioleas M. Breast cancer incidence in Greek women in relation to ABO blood groups and Rh factor. *Int Semin Surg Oncol.* 2009;6:14.
doi: 10.1186/1477-7800-6-14
79. Tryggvadottir L, Tulinius H, Robertson JM. Familial and sporadic breast cancer cases in Iceland: A comparison related to ABO blood groups and risk of bilateral breast cancer. *Int J Cancer.* 1988;42(4):499-501.
doi: 10.1002/ijc.2910420405
80. Anderson DE, Haas C. Blood type A and familial breast cancer. *Cancer.* 1984;54(9):1845-1849.
doi: 10.1002/1097-0142(19841101)54:9<1845:aid-cnrcr2820540913>3.0.co;2-5
81. Cao X, Wen ZS, Sun YJ, Li Y, Zhang L, Han YJ. Prognostic value of ABO blood group in patients with surgically resected colon cancer. *Br J Cancer.* 2014;111(1):174-180.
doi: 10.1038/bjc.2014.302
82. Rashid G, Bhat GA, Rather TB, et al. ABO and Rhesus blood group markers as predictors in colorectal cancer: A prospective observational study. *Medicine (Baltimore).* 2023;102(47):e36256.
doi: 10.1097/MD.00000000000036256
83. Jodat H, Jodat J, Khodadadi A, Talaiezadeh A, Joudaki N, Asadirad A. A study of association of ABO and Rh blood group with colorectal cancer in Khuzestan province, Iran. *Int J Hematol Oncol Stem Cell Res.* 2023;17(4):275-280.
doi: 10.18502/ijhoscr.v17i4.13919
84. Khalili H, Wolpin BM, Huang ES, et al. ABO blood group and risk of colorectal cancer. *Cancer Epidemiol Biomarkers Prev.* 2011;20(5):1017-1020.
doi: 10.1158/1055-9965.EPI-10-1250
85. Li B, Tan B, Chen C, Zhao L, Qin L. Association between the ABO blood group and risk of common cancers. *J Evid Based Med.* 2014;7(2):79-83.
doi: 10.1111/jebm.12098
86. Zhang WN, Liang WJ, Zhang Y, et al. Molecular characteristics of patients with colorectal signet-ring cell carcinoma with different ABO blood groups. *Heliyon.* 2024;10(13):e34220.
doi: 10.1016/j.heliyon.2024.e34220
87. Wei S, Yi T, OuYang Z, Wu J. Association between ABO blood type and type I endometrial cancer: A retrospective study. *J Obstet Gynaecol.* 2023;43(1):2153026.
doi: 10.1080/01443615.2022.2153026
88. Bahardoust M, Dehkharghani MZ, Ebrahimi P, et al. Effect of ABO blood group on postoperative overall survival and recurrence-free survival rate in patients with hepatocellular carcinoma after hepatectomy: A multi-center retrospective cohort study. *BMC Surg.* 2023;23(1):324.
doi: 10.1186/s12893-023-02236-8
89. Ferlay J, Colombet M, Soerjomataram I, et al. Estimating the global cancer incidence and mortality in 2018: GLOBOCAN sources and methods. *Int J Cancer.* 2019;144(8):1941-1953.
doi: 10.1002/ijc.31937
90. Wang GN, Zhou S, Chen C, et al. O Blood type is associated with unfavorable distant-metastasis-free survival in female patients with nasopharyngeal carcinoma: A retrospective study of 2439 patients from epidemic area. *J Cancer.* 2019;10(5):1297-1306.
doi: 10.7150/jca.28372
91. Stakišaitis D, Juknevičienė M, Ulys A, et al. ABO blood group polymorphism has an impact on prostate, kidney and bladder cancer in association with longevity. *Oncol Lett.* 2018;16(1):1321-1331.
doi: 10.3892/ol.2018.8749
92. Kvist E, Krogh J, Hjortberg P. Prognostic variables in patients with prostate cancer: Influence of blood group ABO (H), the Rhesus system, age, differentiation, tumour stage and metastases. *Int Urol Nephrol.* 1992;24(4):417-423.
doi: 10.1007/BF02550636
93. Markt SC, Shui IM, Unger RH, et al. ABO blood group alleles and prostate cancer risk: Results from the breast and prostate cancer cohort consortium (BPC3). *Prostate.* 2015;75(15):1677-1681.
doi: 10.1002/pros.23035
94. Wajsman Z, Saroff J, Murphy GP. Blood group distribution in prostatic cancer patients. *J Surg Oncol.* 1977;9(3):289-291.
doi: 10.1002/jso.2930090311
95. Chastonay P, Hurlimann J, Gardiol D. Biological tissue markers in benign and malignant disease of the human prostate. *Virchows Arch A Pathol Anat Histopathol.* 1986;410(3):221-229.
doi: 10.1007/BF00710828
96. Ghazizadeh M, Kagawa S, Takigawa H, Kurokawa K, Numoto S. Specific red cell adherence test in benign and malignant lesions of the prostate. *Br J Urol.* 1983;55(4):405-407.
doi: 10.1111/j.1464-410x.1983.tb03332.x
97. Abel PD, Marsh C, Henderson D, Leatham A, Powell PH, Williams G. Detection of blood group antigens in frozen sections of prostatic epithelium. *Br J Urol.* 1987;59(5):430-435.
doi: 10.1111/j.1464-410x.1987.tb04841.x

98. Kasperzyk JL, Finn SP, Flavin R, *et al.* Prostate-specific membrane antigen protein expression in tumor tissue and risk of lethal prostate cancer. *Cancer Epidemiol Biomarkers Prev.* 2013;22(12):2354-2363.
doi: 10.1158/1055-9965.EPI-13-0668
99. Ohno Y, Ohori M, Nakashima J, *et al.* Associations between ABO blood groups and biochemical recurrence after radical prostatectomy. *Int J Clin Exp Med.* 2015;8(2):2642-2648.
100. Breimer ME, Mölne J, Nordén G, Rydberg L, Thiel G, Svalander CT. Blood group A and B antigen expression in human kidneys correlated to A1/A2/B, Lewis, and secretor status. *Transplantation.* 2006;82(4):479-485.
doi: 10.1097/01.tp.0000231697.15817.51
101. Lee C, You D, Sohn M, *et al.* Prognostic value of ABO blood group in patients with renal cell carcinoma: Single-institution results from a large cohort. *J Cancer Res Clin Oncol.* 2015;141(8):1441-1447.
doi: 10.1007/s00432-015-1908-3
102. De Martino M, Waldert M, Haitel A, Schatzl G, Shariat SF, Klatt T. Evaluation of ABO blood group as a prognostic marker in renal cell carcinoma (RCC). *BJU Int.* 2014;113(5b):E62-66.
doi: 10.1111/bju.12436
103. Joh HK, Cho E, Choueiri TK. ABO blood group and risk of renal cell cancer. *Cancer Epidemiol.* 2012;36(6):528-532.
doi: 10.1016/j.canep.2012.07.001
104. Abegaz SB. Human ABO Blood Groups and their associations with different diseases. *Biomed Res Int.* 2021;2021:6629060.
doi: 10.1155/2021/6629060
105. Milas I, Kaštelan Ž, Petrik J, *et al.* ABO blood type and urinary bladder cancer: Phenotype, genotype, Allelic association with a clinical or histological stage and recurrence rate. *Glob Med Genet.* 2024;11(3):233-240.
doi: 10.1055/s-0044-1788614
106. Llopis B, Ruiz JL, Server G, Marty M, Gallego J, Jiménez-Cruz JE. ABO blood groups and bladder carcinoma. *Eur Urol.* 1990;17(4):289-292.
doi: 10.1159/000464061
107. Klatt T, Xylinas E, Rieken M, *et al.* Impact of ABO blood type on outcomes in patients with primary nonmuscle invasive bladder cancer. *J Urol.* 2014;191(5):1238-1243.
doi: 10.1016/j.juro.2013.11.106
108. Poole EM, Gates MA, High BA, *et al.* ABO blood group and risk of epithelial ovarian cancer within the Ovarian Cancer Association Consortium. *Cancer Causes Control.* 2012;23(11):1805-1810.
doi: 10.1007/s10552-012-0059-y
109. Yuzhalin AE, Kutikhin AG. ABO and Rh blood groups in relation to ovarian, endometrial and cervical cancer risk among the population of South-East Siberia. *Asian Pac J Cancer Prev.* 2012;13(10):5091-5096.
doi: 10.7314/apjcp.2012.13.10.5091
110. Mitra S, Mondal S, Basu A. The study of ABO blood groups in cancer of the female genital organs and cancer of the breast. *Cancer.* 1962;15(1):39-41.
doi: 10.1002/1097-0142(196201/02)15:1<39:aid-cnrcr2820150106>3.0.co;2-x
111. Newell GR, Gordon JE, Monlezun AP, Horwitz JS. ABO blood groups and cancer. *J Natl Cancer Inst.* 1974;52(5):1425-1430.
doi: 10.1093/jnci/52.5.1425
112. Tailor HJ, Rajani AD, Hathila RN, Patel PR. Relationship between ABO blood Group and Carcinoma of Cervix in South Gujarat Women. *Ann Pathol Lab Med.* 2020;7(3):A107-A110.
doi: 10.21276/apalm.2637
113. Mittal VP. Blood groups and cancer of the cervix uteri. *J Obstet Gynaecol India.* 1970;20(2):240-242.
114. Segi M, Fujisaku S, Kurihara M, Moniwa H. Cancer of cervix uteri and ABO blood groups. *Tohoku J Exp Med.* 1957;66(1):50.
doi: 10.1620/tjem.66.50
115. Kaur I, Singh IP, Bhasin MK. Blood groups in relation to carcinoma of cervix uteri. *Hum Hered.* 1992;42(5):324-326.
doi: 10.1159/000154091
116. Adelusi B. Haemoglobin genotype, ABO blood groups and carcinoma of the cervix. *J Trop Med Hyg.* 1977;80(7):152-154.
117. Mandato VD, Torricelli F, Mastrofilippo V, *et al.* ABO/Rh blood group and cervical cancer survival: Results from our own and other studies. *J Cancer.* 2024;15(15):4777-4788.
doi: 10.7150/jca.95245
118. Lin K, Qiu F, Chen S, He X, Peng S, Chen H. Lack of association between the distribution of ABO blood groups and nasopharyngeal carcinoma in a population of Southern China. *J Cancer Res Ther.* 2018;14(4):785-788.
doi: 10.4103/jcrt.JCRT_567_17
119. Sheng L, Sun X, Zhang L, Su D. ABO blood group and nasopharyngeal carcinoma risk in a population of Southeast China. *Int J Cancer.* 2013;133(4):893-897.
doi: 10.1002/ijc.28087
120. Urun Y, Utkan G, Cangir AK, *et al.* Association of ABO blood group and risk of lung cancer in a multicenter study in Turkey. *Asian Pac J Cancer Prev.* 2013;14(5):2801-2803.
doi: 10.7314/apjcp.2013.14.5.2801
121. Unal D, Eroglu C, Kurtul N, Oguz A, Tasdemir A, Kaplan B. ABO blood groups are not associated with treatment

- response and prognosis in patients with local advanced non-small cell lung cancer. *Asian Pac J Cancer Prev*. 2013;14(6):3945-3948.
doi: 10.7314/apjcp.2013.14.6.3945
122. Xie J, Qureshi AA, Li Y, Han J. ABO blood group and incidence of skin cancer. *PLoS One*. 2010;5(8):e11972.
doi: 10.1371/journal.pone.0011972
123. Cihan YB, Baykan H, Kavuncuoglu E, *et al*. Relationships between skin cancers and blood groups--link between non-melanomas and ABO/Rh factors. *Asian Pac J Cancer Prev*. 2013;14(7):4199-4203.
doi: 10.7314/apjcp.2013.14.7.4199
124. Edgren G, Hjalgrim H, Rostgaard K, *et al*. Risk of gastric cancer and peptic ulcers in relation to ABO blood type: A cohort study. *Am J Epidemiol*. 2010;172(11):1280-1285.
doi: 10.1093/aje/kwq299
125. Li J, Ma X, Chakravarti D, Shalpour S, DePinho RA. Genetic and biological hallmarks of colorectal cancer. *Genes Dev*. 2021;35(11-12):787-820.
doi: 10.1101/gad.348226.120
126. Housset M, Maulard C, Chretien Y, *et al*. Combined radiation and chemotherapy for invasive transitional-cell carcinoma of the bladder: A prospective study. *J Clin Oncol*. 1993;11(11):2150-2157.
doi: 10.1200/JCO.1993.11.11.2150
127. Hanprasertpong J, Jiamset I, Atjimakul T. Prognostic value of ABO blood group in patients with early stage cervical cancer treated with radical hysterectomy with pelvic node dissection. *Tumour Biol*. 2016;37(6):7421-7430.
doi: 10.1007/s13277-015-4626-1
128. Sharma SV, Bell DW, Settleman J, Haber DA. Epidermal growth factor receptor mutations in lung cancer. *Nat Rev Cancer*. 2007;7(3):169-181.
doi: 10.1038/nrc2088
129. Yuzhalin AE, Kutikhin AG. Integrative systems of genomic risk markers for cancer and other diseases: Future of predictive medicine. *Cancer Manag Res*. 2012;4:131-135.
doi: 10.2147/CMAR.S30855