RESEARCH ARTICLE

Influence of Genotype and Haplotype of MDR1 (C3435T, G2677A/T, C1236T) on the Incidence of Breast Cancer - a Case-Control Study in Jordan

Ali M Abuhaliema*, Al-Motassem F Yousef, Nirmeen N El-Madany, Nailya R Bulatova, Nemah M Awwad, Muhammad A Yousef, Khalil Z Al Majdalawi

Abstract

Background: Breast cancer is the leading cause of cancer death among women and the second in humans worldwide. Many published studies have suggested an association between MDR1 polymorphisms and breast cancer risk. Our aim was to study the association between genetic polymorphism of MDR1 at three sites (C3435T, G2677A/T, and C1236T) and their haplotype and the risk of breast cancer in Jordanian females. Materials and Methods: A case-control study involving 150 breast cancer cases and 150 controls was conducted. Controls were age-matched to cases. The polymerase chain reaction/restriction fragment length polymorphism (PCR-RFLP) technique and sequencing were performed to analyse genotypes. Results: The distribution of MDR1 C3435T genotypes differed between cases and controls [cases, CC 45.3%, CT 41.3%, and TT 13.3%; controls, CC 13.4%, CT 43.3%, and TT 30.2%, p < 0.001]. Similarly, the distribution of G2677A/T significantly differed [cases, GG 43.1%, GT+GA 50.9% and AA+TT 6%; controls, GG 29.6%, GT+GA 50.9%, and AA+TT 19.4%, p = 0.004]. On the other hand, genotype and allelotype distribution of C1236T was not statistically different between cases and controls (p=0.56 and 0.26, respectively). The CGC haplotype increased the risk to breast cancer by 2.5-fold compared to others, while TGC and TTC haplotypes carried 2.5- and 5-fold lower risk of breast cancer, respectively. Conclusions: Genetic polymorphisms of MDR1 C3435T and G2677A/T, but not C1236T, are associated with increased risk of breast cancer. In addition, CGC, TGC and TTC haplotypes have different impacts on the risk of breast cancer. Future, larger studies are needed to validate these findings.

Keywords: Breast cancer - MDR1 - polymorphism - haplotype - Jordan
that may influence the efficacy of processing of the pre-mRNAs, and as a consequence, may influence mRNA stability (Ozdemir et al., 2013; Du et al., 2014). Modulation of the P-gp transporting function may contribute to mutagenesis through accumulation of exogenous toxins and increase the risk of cancer development. Among more than 50 SNPs identified in ABC gene, the most clinically relevant SNPs are C3435T (rs1045642, NC_000007.14; 87509329) in exon 21, G2677A/T in exon 21 (rs2032582, NC_000007.14; 87531302) and C1236T (rs1128503, NC_000007.13; 8750285). Synonymous SNPs as C3435T and C1236T decrease the levels of mRNA expression and, hence, overall P-gp activity (Pongstaporn et al., 2015), whereas, G 2677A/T leads to change of alanine amino acid with serine or threonine. Many studies discussed the relation between the three SNPs and the incidence of breast cancer (Ji et al., 2012; Tulsyan et al., 2014; Gutierrez-Rubio et al., 2015; Kim et al., 2015). However, the findings of these studies are still inconclusive (Wang et al., 2013a; Gutierrez-Rubio et al., 2015).

The aim of this study is to discuss the association between genetic polymorphism of MDR1 at three sites (C3435T, G2677A/T, and C1236T) and their haplotype and the risk of breast cancer among Jordanian women.

**Materials and Methods**

**Study population**

A hospital-based study of 150 breast cancer (BC) women and 150 age-matched healthy individuals was conducted at Al-Basheer Hospital/Amman which is a referral hospital for cancer patients. The study lasted from the 15th of March till the 21st of December 2014. The research was approved by the Ethics Committee [Institutional Review Board, (IRB)] at Al-Basheer Hospital in accordance with the ethical standards on human experimentation (Institutional and National) and with the Helsinki Declaration (IRB no. 17443, 28/11/2013). Each subject gave a sample of his/her blood after detailed explanation of the purpose of the study followed by obtaining an informed consent.

**MDR1 Genotyping**

Venous blood (4 mL) was collected from patients and healthy subjects in K3EDTA-coated tubes. The tubes were kept in icebox and DNA extraction was performed on the same day using “DNA Genomic Wizard” purification kit (Promega Corporation, Wisconsin, USA) according to manufacturer’s instructions. Amplification of the 3 position was done using primers as shown in Table (1) (Princess Haya Biotechnology Centre at the King Abdullah University Hospital, Jordan University for Science and Technology, Irbid, Jordan). The PCR conditions were: 4 minutes of initial denaturation at 95°C, followed by 39 cycles of 95°C for 15 seconds, 60°C for 12 seconds, and 72°C for 15 seconds, with a final extension at 72°C for 10 minutes (Bio-Rad, S1000 Thermal cycler™, USA). The PCR products of C3435T were digested with Dpn II restriction enzyme, the products of C1236T were digested with Hae III, while the genotyping of G2677A/T was done by DNA sequencing for all samples (BigDye Terminator Cycle Sequencing on 3730xl DNA sequences, Genewiz® Co., USA). The digestion fragment sizes for the MDR1C3435T genotypes were: 93, 167, and 172 bp bands for CC; 167, and 265 bp bands for TT; and 93, 167,172, and 265 bp bands for CT, whereas for C1236T; 35, 87, and 234 bp bands for CC; 167, and 265 bp bands for TT; and 93, 167,172, and 234 bp bands for CT. Resulting fragments were separated on 2% agarose gel electrophoresis and visualized using RedSafe™ (New England Biolab, USA) staining.

Findings of the PCR-RFLP were validated by the following: 1) A negative control was run simultaneously with every PCR run. A negative control contained all PCR components except the DNA template; 2) 20 % of all samples were repeated to confirm findings of the PCR-RFLP; 3) Randomly selected 10 % PCR-RFLP results were confirmed by DNA sequencing. The concordance between repeated samples, sequencing and PCR-RFLP results was 100%.

**Haplotype analysis**

We analyzed the haplotype frequencies of the three loci (C3435T, G2677A/T and C1236T) and compared them between BC cases and controls. Haplotype frequencies were calculated using Haploviev software for analysis and visualization of LD and haplotype maps (Barrett et al., 2005), and Multiallelic Interallelic Disequilibrium Analysis Software (MIDAS®, University Technology, Irbid, Jordan). The PCR conditions were: 4 minutes of initial denaturation at 95°C, followed by 39 cycles of 95°C for 15 seconds, 60°C for 12 seconds, and 72°C for 15 seconds, with a final extension at 72°C for 10 minutes (Bio-Rad, S1000 Thermal cycler™, USA). The PCR products of C3435T were digested with Dpn II restriction enzyme, the products of C1236T were digested with Hae III, while the genotyping of G2677A/T was done by DNA sequencing for all samples (BigDye Terminator Cycle Sequencing on 3730xl DNA sequences, Genewiz® Co., USA). The digestion fragment sizes for the MDR1C3435T genotypes were: 93, 167, and 172 bp bands for CC; 167, and 265 bp bands for TT; and 93, 167,172, and 265 bp bands for CT, whereas for C1236T; 35, 87, and 199 bp bands for CC; 87, and 234 bp bands for TT; and 35, 87,199, and 234 bp bands for CT. Resulting fragments were separated on 2% agarose gel electrophoresis and visualized using RedSafe™ (New England Biolab, USA) staining.

Findings of the PCR-RFLP were validated by the following: 1) A negative control was run simultaneously with every PCR run. A negative control contained all PCR components except the DNA template; 2) 20 % of all samples were repeated to confirm findings of the PCR-RFLP; 3) Randomly selected 10 % PCR-RFLP results were confirmed by DNA sequencing. The concordance between repeated samples, sequencing and PCR-RFLP results was 100%.

**Table 1. Primer Sequences Used in Genotyping of MDR1 SNPs**

| SNP      | Position | rs name | Primers sequence | Tm    | GC%  | PCR product size |
|----------|----------|---------|------------------|-------|------|------------------|
| C3435T   | 87509329 | rs1045642 | 5’ACATGCTCCCAGGCTTGATAT’3 | 59.71 | 47.62 | 432 bp          |
| G2677A/T | 87531302 | rs2032582 | 5’TGCACTTCCTAAGGCTATACA’3 | 59.36 | 45.45 |                 |
| C1236T   | 87550285 | rs1128503 | 5’CTCGAAAAGAAGTTAAGGTACAGTG’3 | 58.26 | 45.45 | 229 bp          |

**Table 2. Characteristics of BC Patients**

| Characteristic                         | Mean ±SD or N (%) |
|---------------------------------------|--------------------|
| Age, years                            | 49.9±10.8          |
| Median age at diagnosis( range) years | 49 (23-74)         |
| BMI, kg/m2                            | 28.8±6.3           |
| Number of children                    | 4.2±3              |
| Age at first birth, years             | 19.4±9.9           |
| Nulliparous                           | 22 (16.1)          |
| Age at menarche, years                | 13.5±1.6           |
| Age at menopause, years               | 49.0±4.6           |

SD: standard deviation; BMI: body mass index
Table 3. MDR1 Genotype and Allele Type Distribution among Cases and Controls

| Genotype          | Cases, OR (95% CI) | Controls, OR (95% CI) |
|-------------------|--------------------|-----------------------|
| MDR1 C3435T       |                    |                       |
| CC                | 150 (<0.0001)      | 150 (<0.0001)         |
| CT                | 68 (45.3)          | 40 (26.7)             |
| TT                | 20 (13.3)          | 45 (30)               |
| MDR1 G2677A/T     |                    |                       |
| GG                | 50 (43.1)          | 32 (29.6)             |
| GT+AT             | 59 (50.9)          | 55 (43.9)             |
| AA+TT             | 7 (6)              | 21 (19.4)             |
| MDR1 C1236T       |                    |                       |
| CC                | 56 (37.8)          | 40 (31.7)             |
| CT                | 57 (38.5)          | 52 (41.3)             |
| TT                | 35 (23.6)          | 34 (27)               |

| Allele            | Cases, OR (95% CI) | Controls, OR (95% CI) |
|-------------------|--------------------|-----------------------|
| C                 | 198 (66)           | 145 (48.3)            |
| G                 | 159 (67.3)         | 119 (55.1)            |
| A                 | 14 (1.7)           | 4 (1.8)               |
| T                 | 102 (34)           | 155 (51.7)            |

Statistical analysis

Data were coded and entered into SPSS software version 16 (Chicago, IL). Data of categorical nature were summarized as counts and percentages. Data of continuous nature were summarized as mean ± standard deviation. The relation between categorical vs. categorical variables were evaluated by Chi-square or Fisher exact test as appropriate. The strength of association was assessed by calculating odds ratio (OR) and 95% confidence interval (95% CI) (Cochran, 1954). The relationship between categorical and continuous variables were evaluated by independent sample t-test, ANOVA, Mann Whitney or Kruskal Wallis tests as appropriate. Normality of distribution was assessed by Kolmogorov-Smirnov or Shapiro-Wilk test as appropriate. Homogeneity of variance was evaluated by Levene's test. A p value < 0.05 was considered statistically significant. Hardy-Weinberg Equilibrium was assessed for genotypes assuming degree of freedom = 1 (Rodriguez et al., 2009).

Results

A total of 150 breast cancer patients and 150 control subjects were included in this study. BC patients and control groups were of the same age (49.9±10.8 years). Among BC patients, the median age at diagnosis was 49 years, that at menarche was 13.5±1.6 years and at menopause 49±4.6 years. Table 2 summarizes the demographic and clinical characteristics of BC patients.

Genotype distribution

Study of MDR1 C3435T polymorphism revealed that the homozygote mutant type was found in 13.3% among cases, while among controls wild 30.2%, and higher prevalence of wild type in BC patients compared to controls (p < 0.001). Subjects with (C3435T) T allele were 2 time less likely to suffer from breast cancer (p < 0.0001). As for G2677A/T polymorphism, the prevalence of wild type (GG) was higher among cases compared to controls [50 (43.1%) vs. 32 (29.6%), respectively], while the mutant type (AA+TT) was lower in BC [7 (6%) vs. 21 (19.4%) in controls, (p = 0.004). On the other hand, genotype and allelotype distribution of C1236T was not significantly different between cases and controls (p = 0.56) (Table 3).

Table 4. Haplotype Distribution of MDR1 3435, 2677, and 1236 among Cases and Controls

| Haplotype          | Cases, N=300 | Controls, N=286 | OR (95% CI) |
|--------------------|--------------|-----------------|-------------|
| C3435T-G2677A/T-C1236T |             |                 |             |
| CC 35 / 135 / 45   | 70 (24.4)    | 2.5 (1.8-3.6)   |
| TTT 19 / 54 / 18   | 57 (20)      | 0.9 (0.6-1.3)   |
| CTT 13 / 37 / 12   | 45 (15.6)    | 0.8 (0.5-1.2)   |
| TGC 13 / 25 / 8    | 55 (19.4)    | 0.4 (0.2-0.7)   |
| TGT 6 / 18 / 6     | 20 (6.9)     | 0.8 (0.4-1.6)   |
| CGT 5 / 21 / 7     | 13 (4.5)     | 1.6 (0.8-3.2)   |
| TTC 3 / 4 / 1      | 15 (5.2)     | 0.2 (0.08-0.7)  |
| CTC 2.8 / 5 / 1.6  | 12 (4.2)     | 0.4 (0.1-1.1)   |

MDR1 Haplotype

The most common haplotypes were CGC and TTT, while the least common haplotypes were TTC and CTC among both cases and controls. Three haplotypes were distributed differently between cases and controls. CGC haplotype is associated with 2-fold increase in the risk of breast cancer compared to others [OR=2.5, 95% CI (1.8-3.6), p < 0.001] while the TGC and TTC haplotypes were protective. Carriers of TGC had 2.5times lower risk of breast cancer compared to others [OR=0.4, 95% CI (0.2-0.7), p < 0.001], while carriers of TTC haplotype had 5times lower risk of breast cancer [OR=0.2, 95% CI (0.08-0.7), p=0.007]. Table 4 summarises the association between haplotypes and incidence of breast cancer.

DOI:http://dx.doi.org/10.7314/APJCP.2016.17.1.261
The strongest linkage disequilibrium (LD) was observed between SNPs at 2677 and 1236 in cases and controls [cases: $D'=0.92$, controls: $D'=0.54$] (Table 5). The linkage disequilibrium was significant between all pairs of SNPs among cases but not among controls.

### Discussion

MDR1 gene is a member of the ABC family that encodes P-gp, an ATP-dependent efflux pump that helps the cell to get rid of toxins and exogenous materials (Kreidle et al., 2014). Many studies suggested that polymorphism of MDR1 gene may modulate risk of breast cancer due to the absence of protective effect provided by this pump (Ikeda et al., 2015). We studied the association between genetic polymorphism of MDR1 and the risk of breast cancer among Jordanian patients.

Our results indicate that C3435T CC genotype is significantly associated with increased risk of breast cancer. Zubor et al. (2007), reported that, among patients in Slovak Republic, those carrying CC genotype of C3435T had increased risk of breast cancer. In a study by Macias-Gomez et al. (2014) conducted among Mexicans the prevalence of the TT genotype was 8% for patients with fibrocystic changes (FCC), 13% for infiltrating ductal breast cancer (IDBC) and 24% for control samples.

In a meta-analysis published in 2012 that involved 7 studies, MDR1 C3435T polymorphism was significantly associated with increased risk of breast cancer (TT vs CC, OR = 1.66, 95% CI (1.24-2.21) (Wang et al., 2012). A meta-analysis published in 2013 based on 52 studies, included 9 studies that analysed the association of breast cancer and C3435T polymorphism showed similar results [TT vs CC: $D'=1.18$, 95%CI (0.869-1.621), $p=0.001$] (Wang et al., 2013b). There are some limitations in this meta-analysis including asymmetry of its funnel plot suggesting potential publication bias, a language bias, and lack of publication of trials with opposite results. The pre-existing publication bias would question the findings of this meta-analysis. Additionally, this meta-analysis suffered from significant heterogeneity.

On the other hand, a meta-analysis conducted in 2011 did not find any association between MDR1 C3435T polymorphism and risk of breast cancer (Lu et al., 2011). Fawzy et al. (2014) studied 190 Egyptian females with breast cancer and showed that the frequency of TT genotype of C3435T and T allele were significantly higher in breast cancer patients compared to the controls (P < 0.05) while no significant differences were found between the frequencies of MDR1 G2677A/T and C1236T genotypes and haplotypes.

The conflicting results of many studies may be caused by multi gene interactions. It may be assumed that TT genotype leads to defect in P-gp function resulting in increasing drug accumulation inside the cells, and resistance to the chemotherapy, though it may be a consequence from other mechanisms. On the other hand, in patients with the CC genotype, there might be a strong linkage disequilibrium with other polymorphisms in the MDR1 gene as well as alterations in the post translational pathway which influences the efficacy and stability of P-gp.

Genotypes distribution of C3435T vary widely among different populations. In Caucasians, the 3435 frequency was reported as CC (22%), CT (50%), and TT (28%) (Hamidovic et al., 2010). In a study conducted among Spanish breast cancer patients MDR1 C3435T allele distribution was (C) 0.52 and (T) 0.48 which were not different from controls, while genotypes were distributed as CC 14 (28%), CT 24 (48%) and TT 12 (24%) (Henriquez-Hernandez et al., 2009). On the other hand, in Korean population, CC, CT, and TT genotypes were found in 50.9%, 10.2%, and 39.9% BC patients, respectively. A study conducted among Jordanian and Sudanese population by Salem, et al (2014) reported that T allele was more prevalent among Jordanians than C allele (CC: 20.7%, CT: 51.7%, TT: 27.6%; C: 47%, T: 53%). Jordanians resembled Asians and Europeans but were different significantly from Africans (Salem et al., 2014).

Our results indicate that the wild type of 2677G polymorphism is associated with increased risk of breast cancer. These findings are concordant with those in a study by Rubis et al. (2012) that involved 209 patients and 202 controls from Poland [cases: GG = 43.5, GT+GA = 44.5 and AA+TT = 12%; controls: GG = 34%, GT+GA = 52.5% and AA+TT = 13.5%]. On the other hand, in Korean population, CC, CT, and TT genotypes were not different from controls, while genotypes were distributed as CC 14 (28%), CT 24 (48%) and TT 12 (24%) (Hamidovic et al., 2010). In a study conducted among Jordanian and Sudanese population by Salem, et al (2014) reported that T allele was more prevalent among Jordanians than C allele (CC: 20.7%, CT: 51.7%, TT: 27.6%; C: 47%, T: 53%). Jordanians resembled Asians and Europeans but were different significantly from Africans (Salem et al., 2014).

Regarding C1236T polymorphism, our results showed no significant association with the incidence of breast cancer. These findings are consistent with a recent meta-analysis, which reported lack of association between C1236T genetic polymorphism and the incidence of cancer in general (Wang et al., 2013a). Wu et al. (2012), reported that T allele of G2677A/T carried 1.83 higher risk of developing breast carcinoma.

The conflicting results of many studies may be caused by multi gene interactions. It may be assumed that TT genotype leads to defect in P-gp function resulting in increasing drug accumulation inside the cells, and resistance to the chemotherapy, though it may be a consequence from other mechanisms. On the other hand, in patients with the CC genotype, there might be a strong linkage disequilibrium with other polymorphisms in the MDR1 gene as well as alterations in the post translational pathway which influences the efficacy and stability of P-gp.

| Variable | Haplotype | Cases | Controls |
|----------|-----------|-------|----------|
|          | D'        | $r^2$ | X$^2$    | D'        | $r^2$ | X$^2$ |
| 3435-2677 | 0.6       | 0.31  | 36.6     | 0.05      | 0.002 | 0.21  |
| 3435-1236 | 0.57      | 0.22  | 32.4     | 0.004     | 0.0017|        |
| 2677-11236| 0.92      | 0.52  | 60.6     | 0.54      | 0.29  | 26.11 |

$D'$: theoretical range of the linkage disequilibrium coefficient; $r^2$: the square of the correlation coefficient between two indicator variables; X$^2$: Chi-Squared with one degree of freedom
against breast cancer. On the other hand, Wu et al. (2012) reported that TTT haplotype is significantly increases the risk of breast carcinoma. The frequencies of haplotypes reported in this study are in line with a recently published MDR1 haplotypes among apparently healthy Jordanians by Al-Diab et al. (2015) with the most prominent haplotype being CGC (37.6%), followed by TTT (18.6%), and the least frequent haplotype being CTC (1.8%).

Acknowledgements

The authors would like to thank the staff nurses and physicians of the Oncology Department at Al-Basheer Hospital for their huge assistance and patience. The authors would like to extend their gratitude to all the research participants for their wonderful participation and cooperation. This study was supported, in part, by unconditional grant from the Deanship of Scientific Research (The University of Jordan, Jordan).

References

Al-Diab O, Yousef A-M, Al Manassrah E, et al (2015). Genotype and Haplotype analysis of ABCB1 at 1236, 2677 and 3435 among Jordanian population. Trop J Pharm Res, 14, 1013-9.
Al Rifai RO, Nakamura K (2015). Differences in breast and cervical cancer screening rates in Jordan among Women from different socioeconomic strata: analysis of the 2012 population-based household survey. Asian Pac J Cancer Prev, 16, 6697-704.
Alsaif AA, Hasan TN, Shafi G, et al (2013). Association of multiple drug resistance-1 gene polymorphism with multiple drug resistance in breast cancer patients from an ethnic Saudi Arabian population. Cancer Epidemiol, 37, 762-6.
Awad N, Yousef AM, Abuhalleema A, et al (2015). Relationship between Genetic Polymorphisms in MTHFR (C677T, A1298C and their Haplotypes) and the Incidence Of Breast Cancer among Jordanian Females--Case-Control Study. Asian Pac J Cancer Prev, 16, 5007-11.
Barrett JC, Fry B, Maller J, et al (2005). Haploview: analysis and visualization of LD and haplotype maps. Bioinformatics, 21, 263-5.
Cochran G (1954). Some methods for strengthening the common χ tests. Biometrics, 10, 417-51.
de Oliveira J, Felipe AV, Neto RA, et al (2014). Association between ABCB1 immuno histochemical expression and overall survival in gastric cancer patients. Asian Pac J Cancer Prev, 15, 6935-8.
Du Y, Su T, Zhao L, et al (2014). Associations of polymorphisms in DNA repair genes and MDR1 gene with chemotherapy response and survival of non-small cell lung cancer. Fawzy MS, Awad HA, Ahmad HS, et al (2014). Multi-drug resistance 1 genetic polymorphisms gene expression and prediction of chemotherapy response in breast cancer Egyptian patients. Egypt J Biochem Mol Biol, 32, 75-98.
Gaunt TR, Rodriguez S, Zapata C, et al (2006). MIDAS: software for analysis and visualisation of interallelic disequilibrium between multiallelic markers. BMC Bioinformatics, 7, 227.
Global Health Estimates, WHO. 2013. [Accessed 14 June 2015]. Gutierrez-Rubio SA, Quintero-Ramos A, Duran-Cardenas A, et al (2015). 1236 C/T and 3435 C/T polymorphisms of the ABCB1 gene in Mexican breast cancer patients. Genet Mol Res, 14, 1250-9.
Hamidovic A, Hahn K, Kolesar J (2010). Clinical significance of ABCB1 genotyping in oncology. J Oncol Pharm Pract, 16, 39-44.
Henriquez-Hernandez LA, Murias-Rosales A, Hernandez Gonzalez A, et al (2009). Gene polymorphisms in TYMS, MTHFR, p53 and MDR1 as risk factors for breast cancer: a case-control study. Oncol Rep, 22, 1425-33.
Ikeda M, Tsuji D, Yamamoto K, et al (2015). Relationship between ABCB1 gene polymorphisms and severe neutropenia in patients with breast cancer treated with doxorubicin/cyclophosphamide chemotherapy. Drug Metab Pharmacokinet, 30, 149-53.
Ji M, Tang J, Zhao J, et al (2012). Polymorphisms in genes involved in drug detoxification and clinical outcomes of anthracycline-based neoadjuvant chemotherapy in Chinese Han breast cancer patients. Cancer Biol Ther, 13, 264-71.
Kalinsky K, Mayer JA, Xu X, et al (2015). Correlation of hormone receptor status between circulating tumor cells, primary tumor, and metastasis in breast cancer patients. Clin Transl Oncol, 17, 539-46.
Kim HJ, Im SA, Keam B, et al (2015). ABCB1 polymorphism as prognostic factor in breast cancer patients treated with docetaxel and doxorubicin neoadjuvant chemotherapy. Cancer Sci, 106, 86-93.
Kim JL, Cho KH, Park EC, et al (2014). A single measure of cancer burden combining incidence with mortality rates for worldwide application. Asian Pac J Cancer Prev, 15, 433-9.
Kreile M, Rots D, Pickluse L, et al (2014). Lack of association between polymorphisms in genes MTHFR and MDR1 with risk of childhood acute lymphoblastic leukemia. Asian Pac J Cancer Prevent, 15, 9707-11.
Lecarpentier J, Nogues C, Mouret-Fourme E, et al (2015). Breast cancer risk associated with estrogen exposure and truncating mutation location in BRCA1/2 Carriers. Cancer Epidemiol Biomarkers Prev, 24, 698-707.
Lu PH, Wei MX, Yang J, et al (2011). Association between two polymorphisms of ABCB1 and breast cancer risk in the current studies: a meta-analysis. Breast Cancer Res Treat, 125, 537-43.
Macias-Gomez NM, Gutierrez-Angulo M, Leal-Ugarte E, et al (2014). MDR1 C3435T and C1236T polymorphisms in cancer patients with breast cancer. Genet Mol Res, 13, 5018-24.
Ozdemir S, Uludag A, Silan F, et al (2013). Possible roles of the xenobiotic transporter P-glycoproteins encoded by the MDR1 3435 C>T gene polymorphism in differentiated thyroid cancers. Asian Pac J Cancer Prevent, 14, 3213-7.
Payande H, Sadeghi M, Sadeghi E (2015). Differences in prognostic factors between early and late recurrence breast cancers. Asian Pac J Cancer Prevent, 16, 6575-9.
Pongstaporn W, Pakakasama S, Chaksangchaichte P, et al (2015). MDR1 C3435T and C1236T polymorphisms: association with high-risk childhood acute lymphoblastic leukemia. Asian Pac J Cancer Prevent, 16, 2839-43.
Rodriguez S, Gaunt TR, Day IN (2009). Hardy-Weinberg equilibrium testing of biological ascertainment for Mendelian randomization studies. Am J Epidemiol, 169, 505-14.
Rubis B, Holsyz H, Barczak W, et al (2012). Study of ABCB1 polymorphism frequency in breast cancer patients from Poland. Pharmacol Rep, 64, 1560-6.
Salem AH, Ali M, Ibrahim A, et al (2014). Genotype and Allele Frequencies of MDR-1 Gene Polymorphism in Jordanian and Sudanese Populations. American Journal of Medicine Studies, 2, 19-23.
Sufian SN, Masroor I, Mirza W, et al (2015). Evaluation of common risk factors for breast carcinoma in females: a hospital based study in karachi, Pakistan. Asian Pac J Cancer Prevent, 16, 6347-52.
Tulsyan S, Chaturvedi P, Singh AK, et al (2014). Assessment
of clinical outcomes in breast cancer patients treated with taxanes: multi-analytical approach. *Gene, 543*, 69-75.

Wang J, Wang B, Bi J, et al (2012). MDR1 gene C3435T polymorphism and cancer risk: a meta-analysis of 34 case-control studies. *J Cancer Res Clin Oncol, 138*, 979-89.

Wang LH, Song YB, Zheng WL, et al (2013a). The association between polymorphisms in the MDR1 gene and risk of cancer: a systematic review and pooled analysis of 52 case-control studies. *Cancer Cell Int, 13*, 46.

Wang Z, Wang T, Bian J (2013b). Association between MDR1 C3435T polymorphism and risk of breast cancer. *Gene, 532*, 94-9.

Wu H, Kang H, Liu Y, et al (2012). Roles of ABCB1 gene polymorphisms and haplotype in susceptibility to breast carcinoma risk and clinical outcomes. *J Cancer Res Clin Oncol, 138*, 1449-62.

Zhu CY, Lv YP, Yan DF, et al (2013). Knockdown of MDR1 increases the sensitivity to adriamycin in drug resistant gastric cancer cells. *Asian Pac J Cancer Prev, 14*, 6757-60.

Zubor P, Lasabova Z, Hatok J, et al (2007). A polymorphism C3435T of the MDR-1 gene associated with smoking or high body mass index increases the risk of sporadic breast cancer in women. *Oncol Rep, 18*, 211-7.