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Development of Novel Dual Inhibitor of Chemokine Receptor 4 and Mcl-1 Against Multiple Myeloma

Kuntal Bhowmick  
*Rowan University*

Kristy K. Patel  
*Rowan University*

Suman Pathi  
*Rowan University*

Subash Jonnalagadda  
*Rowan University*

Tulin Budak-Alpdogan  
*Rowan University*

See next page for additional authors

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Author(s)
Kuntal Bhowmick, Kristy K. Patel, Suman Pathi, Subash Jonnalagadda, Tulin Budak-Alpdogan, and Manoj K. Pandey
Multiple myeloma (MM) is a neoplastic plasma-cell disorder. It is characterized by clonal proliferation of malignant plasma cells in the bone-marrow (BM) microenvironment, monochlonal protein in blood or urine, and associated organ dysfunction. The treatment options approved by FDA are immune-modulatory agents, proteasome inhibitors, and autologous stem cell transplantation (ASCT). Unfortunately, MM remains uniformly fatal owing to intrinsic or acquired drug resistance and the median survival time is 3 to 5 years. Thus, there is a great need for novel strategies to combat MM. The intimate relationship of myeloma cells to BM microenvironment is “hallmark of myeloma”. The homing of MM cells to the BM, mediated by the chemokine stromal cell-derived factor-1α (SDF-1α) and its receptor CXCR4 has important functional sequelae. The BM microenvironment constituting cells secrete chemokines, cytokines, and growth factors such as interleukin 6 (IL6), vascular endothelial growth factor (VEGF), SDF-1α, and tumor necrosis factor a (TNFa) etc. These growth factors contribute in activation of several signaling pathways including nuclear factor-κB (NF-κB), phospholipidinositol 3-kinase (PI3K)/Akt, Ras-Raf-MAPK kinase (MEK) extracellular signal regulated kinase (ERK), and the Janus kinase 2 (JAK2)-signal transducer and activator of transcription 3 (STAT3). Activation of these pathways has been associated with increased expression of several anti-apoptotic proteins such as Bcl-2, Bcl-xL, Mcl-1, and XIAP. Collectively, these discoveries highlight that interaction of MM cells to BM microenvironment not only promote growth, survival and migration of MM cells, but also confer resistance to conventional chemotherapy. We hypothesized that an agent capable of inhibiting the migration of myeloma cells to bone marrow and suppressing the expression of survival protein MM should be a better option for MM treatment. We have synthesized a novel dual inhibitor of CXCR4 and Mcl-1. Our in vitro data suggests that this molecule inhibits the expression of CXCR4 and Mcl-1 and survival of MM cells.

**Introduction**

- MM cells are highly dependent on the bone marrow (BM) microenvironment for growth and survival.
- Migration of cells through the blood to the BM niches requires active navigation, a process termed homing.
- One of the most extensively studied chemokines in homing is stromal cell-derived factor-1α (SDF-1α) also known as CXC chemokine ligand 12 (CXCL12) and its receptor, CXCR4.
- The BM microenvironment constituting cells secrete chemokines, cytokines, and growth factors such as interleukin 6 (IL6), vascular endothelial growth factor (VEGF), SDF-1α, and tumor necrosis factor a (TNFa) etc.

**Hypothesis**

- MM cells are highly dependent on the bone marrow (BM) microenvironment for growth and survival.
- Migration of cells through the blood to the BM niches requires active navigation, a process termed homing.
- One of the most extensively studied chemokines in homing is stromal cell-derived factor-1α (SDF-1α) also known as CXC chemokine ligand 12 (CXCL12) and its receptor, CXCR4.
- The BM microenvironment constituting cells secrete chemokines, cytokines, and growth factors such as interleukin 6 (IL6), vascular endothelial growth factor (VEGF), SDF-1α, and tumor necrosis factor a (TNFa) etc.

**Results**

- These growth factors contribute in activation of several signaling pathways including nuclear factor-κB (NF-κB), phospholipidinositol 3-kinase (PI3K)/Akt, Ras-Raf-MAPK kinase (MEK) extracellular signal regulated kinase (ERK), and the Janus kinase 2 (JAK2)-signal transducer and activator of transcription 3 (STAT3). Activation of these pathways has been associated with increased expression of several anti-apoptotic proteins such as Bcl-2, Bcl-xL, Mcl-1, and XIAP. Collectively, these discoveries highlight that interaction of MM cells to BM microenvironment not only promote growth, survival and migration of MM cells, but also confer resistance to conventional chemotherapy. We hypothesized that an agent capable of inhibiting the migration of myeloma cells to bone marrow and suppressing the expression of survival protein MM should be a better option for MM treatment. We have synthesized a novel dual inhibitor of CXCR4 and Mcl-1. Our in vitro data suggests that this molecule inhibits the expression of CXCR4 and Mcl-1 and survival of MM cells.

- We modified GA by adding Mcl-1 inhibitor moxetin in order to develop this molecule as a dual inhibitor of CXCR4 and Mcl-1. We investigated whether the gambogic acid (GA) analog(s) can modulate survival and drug resistance of MM cells.

**Conclusion and future directions**

- Our data showed that GA and its analog mediate their effects by targeting MM cells and the BM microenvironment. (A) GA targets CXCR4 receptor, (B) directly inhibits MM cell growth, (C) inhibits angiogenesis, (D) decrease cytokine production and sequestration such as osteoclastogenesis, and whether inhibits MM cell adhesion to BM accessory cells (E) will be explored.

**References**


**Figure 1.** The intimate relationship between MM and BM microenvironment. BMSCs secrete cytokine a growth factors that these growth factors activate several pathways in MM. GA targets these pathways.

**Figure 2.** GA interacts with CXCR4 and modulates the expression of CXCR4 protein of MM cells

**Figure 3.** A, GA analogs reduce the survival of MM cells. MM cells (RPMI 8226 and U266) were treated with different concentration of GA, and its analogs for 48h. Cell viabilities were assessed using MTT assay. As shown in the figure treatment of GA and its analog effectively kill MM cells. Prism software was used to plot the graph. B, Effect of GA analog on survival protein in human MM RPMI 8226 cells treated with the indicated amount of GA analog for 14h. Treatment of GA analog modulates expression of anti-apoptotic proteins such as Mcl-1, Bcl-2, and caspase 3.

**Figure 4.** Our data showed that GA and its analog mediate their effects by targeting MM cells and the BM microenvironment. (A) GA targets CXCR4 receptor, (B) directly inhibits MM cell growth, (C) inhibits angiogenesis, (D) decrease cytokine production and sequestration such as osteoclastogenesis, and whether inhibits MM cell adhesion to BM accessory cells (E) will be explored.

**Figure 5.** Growth/survival stimuli in MM cells and CD138+ MM plasma cells.

**Figure 6.** Gambogic acid (GA) and its analogs modulates the expression of CXCR4 protein of MM cells

**Figure 7.** Gambogic acid (GA) and its analogs modulates the expression of CXCR4 protein of MM cells