



## Review Article

## CCR5 antagonist: Promising agents in HIV treatment

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## ABSTRACT

HIV enters the bloodstream via binding to receptors on the surface of host cells. The CD4+ cell is a kind of white blood cell. Viral access to It all starts with the CD4+ cell. R5 HIV-1 Virus Attachment gp120 (glycoprotein 120) to The CD4+ T-cell receptor (CD4+ TCR) is a type of T-cell receptor that gives rise to a conformational a modification in gp120 that enables it to connect to CCR5, causing it to activate gp41 (glycoprotein 41) mediates the viral envelope is fused with membrane of the cell and the nucleocapsid makes its way into the host a cell. CCR5 is a kind of co-receptor by inhibiting CCR5 cell surface, antagonists prevent HIV-1 from entering and infecting immune cells receptor. CCR5 antagonists are small molecules that attach to a hydrophobic pocket produced by CCR5. The CCR5 receptor's trans membrane helices They're thought to interact with the receptor in the brain. The review gives a brief description of currently used CCR5 antagonists.

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## 1. Introduction

CCR5 receptor antagonists are a type of tiny chemical that binds to the CCR5 receptor and inhibits it. CCR5, a chemokine receptor with a C-C pattern, is involved in the entry of HIV, the virus that causes AIDS, into cells.<sup>1</sup> As a result, antagonists of this receptor are possible entrance inhibitors. In the treatment of HIV infections, there are a variety of therapeutic options. The viral pathway, for example, is one of the potential targets for pharmacological therapy in the HIV life cycle.<sup>2</sup> The major receptors involved in the HIV entrance process are CCR5 and CXCR4. These receptors are typically expressed on human T cells, dendritic cells, macrophages, and Langerhans cells and belong to the seven trans membrane G-protein-coupled receptor (GPCR) family.<sup>3</sup> They serve as co receptors, allowing HIV type 1 (HIV1) to connect to cells prior to viral fusion and entry

into host cells. R5 and X4 strains of HIV isolates can be distinguished. When the virus uses the co-receptor CCR5, it is called an R5 strain, and when it uses CXCR4, it is called an X4 strain.<sup>4</sup>

Because CCR5 receptors are located on the cell surface, big and tiny compounds have the ability to disrupt the CCR5-viral interaction and prevent viral entrance into human cells.<sup>5</sup>

## 1.1. History

Since the discovery of HIV in the 1980s, there has been significant progress in the development of new antiviral medications. The observation that a tiny number of high risk populations demonstrated either resistance or delayed development of CCR5 antagonists was the catalyst for their discovery. The illness A mutation (CCR5-32) in the gene that codes for the CCR5 receptor was discovered in this population. Scientists discovered the CCR5 receptor, which

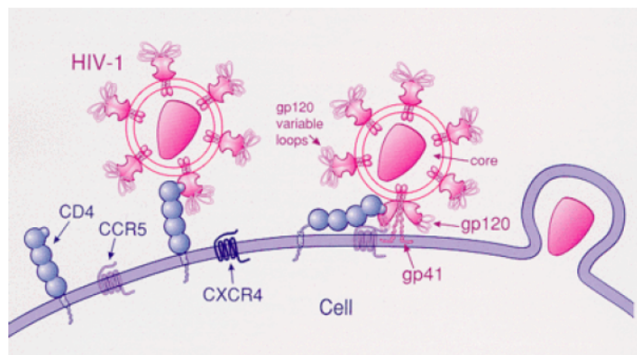
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resulted in nearly full resistance to HIV-1 infection. CCR5 and CXCR4 are cell surface receptors that play an important role in viral fusion infection. It was discovered in 1996 that CCR5 is a co-receptor for the most regularly used opioids. R5 strains of HIV-1 that have been transmitted.

During the early phases of infection, this virus is the most common. R5 is still the prevalent type in almost half of late-stage HIV-1 infected patients, although as a result, strains can mutate into X4 in the future.<sup>6</sup>

### 1.2. Mechanism of action



**Fig. 1:** HIV entry into CD4+ cell via CCR5 co-receptor

HIV enters the bloodstream via binding to receptors on the surface of host cells. The CD4+ cell is a kind of white blood cell. Viral access to it all starts with the CD4+ cell. R5 HIV-1 Virus Attachment gp120 (glycoprotein 120) to the CD4+ T-cell receptor (CD4+ TCR) is a type of T-cell receptor that gives rise to a conformational modification in gp120 that enables it to connect to CCR5, causing it to activate gp41 (glycoprotein 41) mediates the viral envelope is fused with membrane of the cell and the nucleocapsid makes its way into the host cell (Figure 1). CCR5 is a kind of co-receptor on the cell surface, antagonists prevent HIV-1 from entering and infecting immune cells receptor.<sup>7</sup> The CCR5 receptor's trans membrane helices they're thought to interact with the receptor in the brain. An allosteric mechanism that locks the receptor in a conformation that prevents it from interacting with its co-receptor.<sup>8</sup>

## 2. Drug development

The CCR5 receptor is a G-protein coupled receptor, as previously stated (GPCR). Many pharmaceutical companies had already created a sizable business before the revelation of CCR5's function in HIV infection. GPCR-targeting chemicals are a group of compounds that target GPCRs. Some of these chemicals could be used as a starting point. Point for CCR5 antagonist medicinal chemistry, although CCR5 antagonist medicinal chemistry would need to be improved. To increase selectivity and potency, as well as

pharmacokinetic qualities. A significant issue was the lack of the hERG ion channel has a high affinity for available screening hits; blockage of hERG causes QT syndrome. Prolonged intervals can raise the risk of deadly ventricular arrhythmias.<sup>9</sup>

Many CCR5 antagonists have been studied by pharmaceutical companies, but few of them have actually reached human efficacy studies; for example AstraZeneca, Novartis, Merck, and Takeda have used their GPCR-targeting compound collections to develop a potent CCR5 antagonist, but none of them have reached clinical trials. Three pharmaceutical companies were in competition to be the first to have a small molecule CCR5 antagonist approved: Glaxo Smith Kline (GSK) with their compound aplaviroc, Schering-Plough with vicriviroc, and Pfizer with maraviroc. All of the compounds reached clinical trials in humans; only maraviroc has been approved by the U.S. Food and Drug Administration (FDA).<sup>10</sup>

### 2.1. Leronlimab

Leronlimab is a humanized monoclonal antibody targeted in opposition to the CCR5 receptor found on T lymphocytes of the human immune system and many kinds of cancers. It is being investigated as a capability therapy inside the treatment of HIV infection, graft as opposed to host sickness (NCT02737306) and metastatic cancer (NCT03838367). The USA food and Drug administration (FDA) has certain Leronlimab for instant-tune approval. In February 2008, the drug entered segment 2 clinical trials and a phase 3 trial become started in 2015. In February 2018 Cyto Dyn Inc. said that the number one endpoint has been achieved within the pro a hundred and forty pivotal aggregate therapy trial in HIV contamination.<sup>11,12</sup>

Leronlimab is being developed by Cyto Dyn Inc. In May 2007, effects from the segment I scientific trial of the drug established "robust, fast, extended, dose-based, notably considerable antiviral pastime" for Leronlimab. Members within the maximum-dosing institution obtained 5 milligrams in keeping with kilogram and confirmed a mean viral load decrease of -1.eighty three log<sub>10</sub>. On common, discounts of more than -1 log<sub>10</sub> consistent with millilitre were maintained for between two and 3 weeks, from only a unmarried dose of the drug. The biggest man or woman HIV RNA reductions ranged as much as -2.5 log<sub>10</sub> among sufferers receiving both the 2 and 5 mg/kg doses.

Leronlimab is a lab-made antibody that capabilities as an entry inhibitor. Leronlimab binds to the CCR5 receptor on the CD4 cells, and interferes with HIV's capability to go into the cellular. Leronlimab, a humanized form of a PA14 antibody, is a chemokine-receptor CCR5 monoclonal antibody and might inhibit CCR5 tropic HIV-1 at concentrations that do not antagonize the herbal interest

of CCR5 in vitro. HIV-1 access is mediated via the HIV-1 envelope glycoproteins gp120 and gp41. The gp120 will bind CD4 and the CCR5co receptor molecule, and this triggers gp41-mediated fusion of the viral and cell membranes. CCR5 is for this reason wished for the access of the virus and this infection of healthy cells. Leronlimab, the anti-CCR5 monoclonal antibody, can forestall HIV from getting into the cell and forestall viral replication. It prevents the virus-cell binding at a wonderful website online in the CCR5 co-receptor without interfering with its herbal interest. Not like other entry inhibitors, seasoned one hundred forty is a monoclonal antibody. The mechanism of inhibition is aggressive instead of allosteric. As such, it have to be injected to be effective. but, once inside the frame, pro a hundred and forty binds to CCR5 for >60 days, which may additionally allow for dosing as from time to time as each other week. Compared to incredibly-lytically antiretroviral remedy which has been proven to have treatment-associated toxicities for HIV-inflamed sufferers, PRO140 has no multi-drug resistance or toxicities.<sup>13</sup>

In February 2018, Cyto Dyn stated that the primary endpoint has been achieved inside the pro a hundred and forty pivotal mixture remedy trial in HIV contamination and could keep for an additional 24 weeks (end of August 2018) with pro one hundred forty weekly subcutaneous injections and optimized artwork. The file discloses that a unmarried 350 mg subcutaneous injection of seasoned a hundred and forty led to a HIV-1 RNA viral load reduction more than 0.5 log or 68% within one week compared with folks that received a placebo. The primary efficacy endpoint results were supplied at ASM Microbe 2018. Inside the pivotal trial of Leronlimab in mixture with popular anti-retroviral treatment plans in HIV-infected treatment experienced sufferers, eighty 1 % of sufferers completing trial executed HIV viral load suppression of < 50 cp/mL. Recent permitted pills for this populace range from forty three% after 24 weeks to 45% after forty eight weeks with viral load suppression of < 50 cp/mL. In March 2019, Cyto Dyn filed with America FDA the first a part of the BLA for Leronlimab (PRO140) as a combination therapy with HAART in HIV. In might also 2020, the employer filed its BLA with potential FDA approval in 4Q'20. Cyto Dyn is undertaking an investigative monotherapy trial of Leronlimab (PRO140) for HIV. If successful, once consistent with week self-administered Leronlimab would constitute a paradigm shift in remedy of HIV.<sup>14</sup>

Cyto Dyn is investigating the usage of Leronlimab in diverse solid tumours. On February 18, 2019, Cyto Dyn introduced it will start eight pre-clinical research on cancer most cancers, pancreatic, breast, prostate, colon, lung, liver, and belly most cancers. This

has the capability to result in eight section II medical research with Leronlimab in the cancer area. On November 23, 2018, Cyto Dyn obtained FDA approval of its IND submission and allowed to provoke a section Ib/II medical trial for metastatic triple-poor breast most cancers (mTNBC) sufferers. On February 20, 2019, Cyto Dyn announced that Leronlimab wascapable of lessen by greater than 98% the prevalence of human breast most cancers metastasis in a mouse xenograft version for cancer via six weeks with Leronlimab. The temporal equivalency of the murine 6 weeks have a look at can be up to six years in people. In can also 2019, the U.S. meals and Drug administration (FDA) granted rapid song designation for Leronlimab for use in combination with carboplatin for the remedy of sufferers with CCR5-advantageous mTNBC. In July 2019, Cyto Dyn announced the dosing of first mTNBC affected person beneath compassionate use. Simultaneously, the segment Ib/II trial for remedy-naïve mTNBC sufferers is energetic and anticipates pinnacle line statistics in 2020. Ifa success, the records from remedy-naïve mTNBC sufferers should function the premise for probably looking for multiplied US FDA approval.

A study demonstrated Leronlimab reduced the number and size of new human breast cancer metastasis in a mouse model and reduced the size of established metastasis there by extending survival. In May 2019, Cyto Dyn initiated pre-clinical study of Leronlimab to prevent NASH.<sup>15</sup>

## 2.2. Aplaviroc

Aplaviroc is originated from a category of spirodiketopiperazine derivatives. Discern 2 shows the molecular structure of the lead compound and the very last compound aplaviroc. The lead compound confirmed good efficiency in blocking off CCR5 in some of R5 HIV strains and in opposition to multi-drug resistant lines. The hassle with this compound become no longer its CCR5 selectivity however the oral bioavailability. This brought about in addition development of the molecule and the end result become a compound named aplaviroc. Sadly, not with standing the promising preclinical and early clinical outcomes, some intense liver toxicity became discovered within the remedy of naïve and treatment-skilled sufferers that brought about the discontinuation in similarly improvement of aplaviroc.

## 2.3. Vicriviroc

Schering-Plough diagnosed a lively compound at some stage in screening. The molecular shape of the lead compound, intermediate compound, and the very last compound vicriviroc. The lead compound contained a piperazine scaffold and changed into a powerful muscarinic

acetylcholine receptor (M2) antagonist with modest CCR5 pastime. The modifications that had been made at the left hand aspect of the lead compound and the addition of a methyl institution at the piperazine institution ((S)-methylpiperazine) resulted with inside the intermediate compound that had appropriate affinity for CCR5 receptors however very little affinity for muscarinic pastime, however, the compound did display affinity for the hERG ion channel. Further reconstruction caused the improvement of the very last compound vicriviroc, when Schering determined that the pyridyl N-oxide at the intermediate ought to get replaced with the aid of using 4,6- dimethyl pyrimidine carboxamide. Vicriviroc had an first rate selectivity for CCR5 receptors over muscarinic and hERG affinity changed into significantly reduced. Phase I medical trial of vicriviroc gave promising outcomes, so a segment II have a look at with inside the remedy of naïve sufferers changed into initiated. The segment II have a look at changed into discontinued on account that there has been a viral step forward with inside the vicriviroc institution in comparison to the manage institution. These outcomes advised that vicriviroc changed into now no longer powerful with inside the remedy of remedy-naïve sufferers in comparison to cutting-edge treatments. Another segment II medical have a look at changed into finished in remedy-skilled sufferers. The outcomes had been that vicriviroc did have strong antiviral pastime however 5 times of most cancers most of the members had been stated, however, the have a look at changed into persevered on account that there has been loss of causal affiliation of the malignancies and vicriviroc. In overdue 2009, vicriviroc changed into stated with the aid of using the organization to have entered segment II research in remedy for naïve sufferers and segment III research in remedy-skilled sufferers.<sup>16</sup>

#### 2.4. Maraviroc

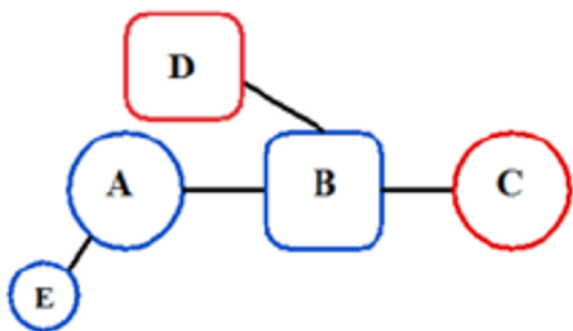
Pfizer became to excessive-throughput screening in their look for a terrific start line for a small molecule CCR5 antagonist. Their screening ended in a compound that supplied susceptible affinity and no antiviral pastime however represented a terrific start line for in addition optimization. Compounds 1–nine in Table 1 display the improvement of maraviroc in few steps. The chemical shape of the beginning molecule (UK- 107,543) is supplied as compound 1. Their first attention turned into to reduce CYP2D6 pastime of the molecule and to lessen its lipophilicity. They replaced the imidazopyridine with benzimidazole and the benzhydryl organization turned into swapped out for a benzamide. The final results turned into compound 2. That compound confirmed precise binding efficiency and the begin of an antiviral pastime. Further shape–pastime relationship (SAR) optimization of the amide region and figuring out the enantiomeric choice brought about the cyclobutyl amide shape in compound

3. However, the hassle with the CYP2D6 pastime of the compound turned into nonetheless unacceptable so that they had to carry out in addition SAR optimization that determined that the [3.2.1]-azabicycloamine (tropane) could update the aminopiperidine moiety. This extrade in the chemical shape brought about compound four. Compound four had no CYP2D6 pastime even as retaining fantastic binding affinity and antiviral pastime. Although compound four confirmed promising results, it validated 99% inhibition at the hERG ion channel. That inhibition turned into unacceptable because it can cause QTc c language prolongation. The studies team then did some changes to peer which a part of the molecule performed a position with inside the hERG affinity.<sup>17</sup> Compound five suggests an analogue that they synthesized which contained an oxygen bridgehead with inside the tropane ring; however, that reconstruction did now no longer have an impact at the hERG affinity. They then centered at the polar floor location with inside the molecule to dial out the hERG affinity. These efforts ended in compound 6. That compound preserved desired antiviral pastime and turned into selective towards the hERG inhibition however the hassle turned into its bioavailability. Reduction with inside the lipophilicity, via way of means of changing the benzimidazole organization with a substituted triazole organization gave compound 7. Compound 7 had proven a vast discount in lipophilicity and maintained the antiviral pastime however again, with the creation of a cyclobutyl organization, the compound confirmed hERG inhibition. Changing the hoop length in compound 7 from a cyclobutyl unit to a cyclopentyl unit in compound eight brought about a vast growth in antiviral pastime and lack of hERG affinity. Further improvement brought about discovery of a four, four'-difluorocyclohexylamide additionally called maraviroc. Maraviroc preserved fantastic antiviral pastime, even as demonstrating no vast hERG binding affinity. The loss of hERG binding affinity turned into expected to be due to the massive length of the cyclohexyl organization and the excessive polarity of the fluoro substituents. In August 2007 the FDA authorized the primary CCR5 antagonist, maraviroc, observed and advanced via way of means of Pfizer.<sup>18</sup>

### 3. Pharmacophore

The predictive Pharmacophore version became evolved for a big collection of piperidine- and piperazine-primarily based totally CCR5 antagonists via way of means of Schering-Plough Research Institute. Their speculation consisted of ordinarily 5 features, hydrogen bond acceptors, marked C and D in discern four and three hydrophobic groups, A, B and E in discern four.<sup>19,20</sup> Part B generally has a primary nitrogen group. The version became tested the usage of diverse set of six CCR5 antagonists from 5 exclusive pharmaceutical companies. The pleasant version

effectively expected these compounds as being exceedingly active. It is feasible to apply the version as a device in digital screening for brand spanking new small molecular CCR5 antagonists and additionally to are expecting organic sports of compounds previous to assignment their luxurious synthesis.<sup>21</sup>



**Fig. 2:** Predictive pharmacophore model for piperidine- and piperazine-based CCR5 antagonists

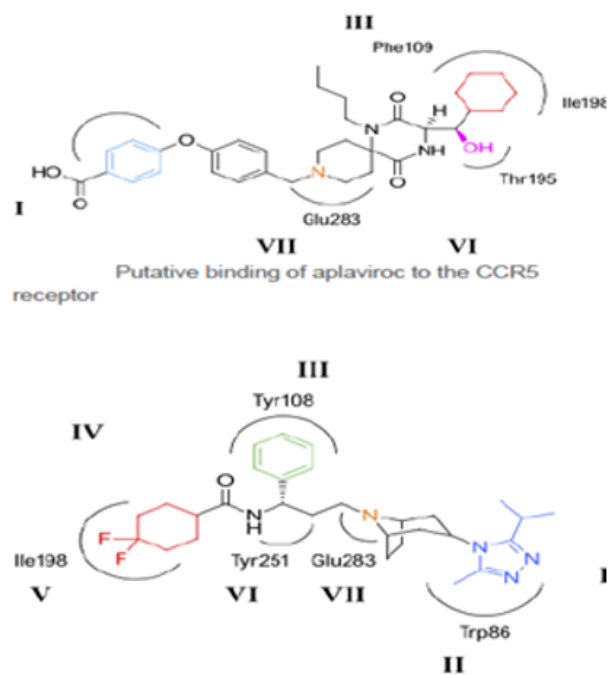
### 3.1. Binding

CCR5 is a member of G protein-coupled, seven trans membrane section receptors. The shape of the receptor accommodates seven-helix package deal with inside the trans membrane region, those areas are classified I– VII. The CCR5 antagonists are anticipated to bind to a putative binding pocket that is buried with inside the trans membrane domain, enclosed via way of means of the seven trans membrane helices. The binding pocket may be very hydrophobic with more than one fragrant residues lining the pocket. The key residues are tryptophan 86 and 248 (Trp86, Trp248), tyrosine 108 and 251 (Tyr108, Tyr251), phenylalanine 109 (Phe109), threonine 195 (Thr195), isoleucine 198 (Ile198), glutamic different in shape and electrostatic potential although they all share the same binding pocket. The interesting thing about the binding of these molecules is that they exhibit significantly different binding modes, although they all establish an extensive interaction network with CCR5.<sup>22</sup>

### 3.2. Aplaviroc

The putative binding mode for aplaviroc is proven in parent 5. The key salt bridge interplay among aplaviroc and Glu283 is expected to be pretty vulnerable as compared to different CCR5 antagonists. The hydroxyl organization on aplaviroc bureaucracy a sturdy hydrogen bond to the polar residue Thr195. This H-bond interplay is the most powerful with aplaviroc as compared to different CCR5 antagonists. The cyclohexyl organization with inside the aplaviroc shape is expected to have interaction with the

receptor in a hydrophobic pocket shaped with the aid of using Ile198, Thr195 and Phe109 and is idea to reveal pretty sturdy hydrophobic interactions. The researchers expect that the butyl organization of aplaviroc is buried with inside the helical package deal through sturdy hydrophobic interplay with multiple fragrant residues of the CCR5 receptor. Aplaviroc has a completely unique function of keeping of the herbal chemokine protein ligands binding to CCR5 and next activation, while maraviroc and the opposite antagonists nearly absolutely block chemokine-CCR5 interactions. This type of interference is to date taken into consideration to be safe, and people that certainly lack CCR5 do now no longer display any apparent fitness problems. However, to restrict the toxicity and aspect results of CCR5 antagonists it would be best a good way to hold the chemokine receptor function. Consequently, it must be of interest to layout inhibitors that especially disrupt CCR5–gp120 binding however do now no longer have an effect on the CCR5 chemokine activation.<sup>23</sup>



**Fig. 3:**

### 3.3. Maraviroc

The putative binding mode for maraviroc is proven in determine 6. The most powerful interplay is estimated to be among maraviroc and glutamic acid (Glu283) thru a sturdy salt bridge interplay. The interplay among tryptophan (Trp86) and maraviroc includes T-formed  $\pi$ - $\pi$  stacking even as the interplay with phenylalanine (Phe109) is anticipated to be hydrophobic. Tyrosine (Tyr108) is thought to engage with the phenyl organization on maraviroc thru a

parallel displaced interplay. The interplay among maraviroc and isoleucine (Ile198) is anticipated to be ordinarily hydrophobic in nature and the interplay among maraviroc and tyrosine (Tyr251) may be very limited.<sup>24</sup>

### 3.4. Other CCR5 antagonists

Development of latest CCR5 antagonists continues, each for his or her antiviral results and additionally for ability application in a variety of autoimmune indications. Researchers at Roche Palo Alto found a unique collection of effective CCR5 small-molecule antagonists. Lead optimization become pursued with the aid of using balancing opposing traits of metabolic balance and potency.<sup>25</sup> Combination of the spiropiperidine template with pharmacophore factors from each aplaviroc, and Schering's CCR5 antagonist program, caused the preliminary lead compound on this collection. Further development of that lead compound caused the invention of compound A in parent 7-a compound that possesses an awesome selectivity and pharmacokinetic properties.<sup>26</sup>

## 4. Conclusion

The CCR5 antagonist INCB009471 has nanomolar pastime towards HIV-1 in vitro. This compound validated strong and extended antiviral pastime towards R5-tropic HIV-1 whilst given 200 mg as soon as each day dose for 14 days.<sup>27,28</sup> These findings supported similarly scientific improvement of INCB009471 and that they have when you consider that stepped forward to section IIb scientific trials. As of 2009 the look at of this compound is inactive and no similarly research are deliberate at this time. Not simplest small molecules however additionally proteins added via way of means of gene remedy had been advised to ablate CCR5 function, and method that has additionally been hired for different HIV targets.<sup>29</sup>

## 5. Source of Funding

None.

## 6. Conflict of Interest

None.


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