ABSTRACT

Hydroxychloroquine (HCQ) as a drug grabbed serious attention of whole world in dealing with COVID-19 pandemic. Recently some in-vitro and in-vivo study showing possible inhibition of SARS-CoV-2 by use of HCQ. However at the same time, some case studies showing NO clinical benefit/ poor clinical outcome with substantial detrimental adverse effects by use of HCQ in treatment of coronavirus disease-2019. Thus, the HCQ use (in COVID-19 treatment) is of current international interest, although a consensus has not yet been reached. More evidences are still required to prove efficacy of HCQ against COVID-19. In view of this, the present review highlights the current ongoing research related to use of HCQ in treatment coronavirus disease-2019. The present review will discuss the possible anti-viral mechanism of HCQ, prophylaxis strategy and effect of HCQ against SARS-CoV-2 virus in-vitro study. Further this review also summarizes and debates all available clinical trials/ case studies of HCQ use against COVID-19 (with clinical outcome). Finally possible detrimental adverse effects are also discussed considering the public health and pharmacovigilance concern.

**Keywords**: Potency of hydroxychloroquine; COVID-19; Coronavirus disease-2019; Clinical trials; SARS-CoV-2; Adverse effects of hydroxychloroquine; Pharmacovigilance concern

1. Introduction:

Year 2020 started with the novel coronavirus 2019 disease (COVID-19) which has been declared a pandemic [1]. It is third extremely pathogenic and contagious coronavirus after endemic SARS-CoV and MERS-CoV appeared in humans [2]. The exact origin, transmission, mechanisms of SARS-CoV-2 is not confirmed and clear now until however, its genome sequence is closely related (76-80 %) with the SARS-CoV coronavirus [2]. As of now (25th April 2020), approximately 29,01,305 patients have confirmed to have COVID-19 infection globally (212 countries) with 2,00,082 fatalities [3]. Development of potential therapy is urgently required in order to prevent pandemic COVID-19. On 30th March 2020, Food and Drug Administration of USA issued an Emergency Use Authorization of HCQ and chloroquine (CQ) for treatment of certain COVID-19 patients [4].

A controversial anti-malaria drug being explored and used in random clinical trials and clinical case studies around the world against potential COVID-19 in order to get relieve from symptoms, or as a preventative measure to stop people being get infected with COVID-19 [5-10]. Some reports showing potential use of the HCQ in treatment of coronavirus disease-2019 (with minimum side effects) [5,6,9]. At the same time some reports are NOT at all supporting potency of HCQ for COVID-19 [7,8,10], conversely they reported increase of adverse events by use of HCQ in COVID-19 patient [10]. Thus, there are several toxic effects of HCQ which are needed to address considering prophylaxis use in view of pharmacovigilance concern [7,8,10]. It may be toxic enough that many people may extensively suffer or may even die due to cardiac problem during the treatment [10]. Hence a very careful analysis is still needed for the use of HCQ in treatment of coronavirus disease-2019 [7,8,10]. Thus, the debate for use...
of the HQ against COVID-19 is of great attention which needs an urgent consideration in order to understand the actual potency of HQ against COVID-19 [5-10]. The use of the HQ medicine in treatment of coronavirus disease-2019 is of current international interest, although a consensus has not yet been reached which may ask for more powerful evidences. In view of this, the present review is done to highlight (i) the antiviral use of HQ against various viruses, (ii) possible mode of action of HQ against SARS-CoV-2, (iii) in-vitro-inhibition of SARS-CoV-2 virus by HQ, (iv) conflicts in-vivo clinical trial/case studies explaining the therapeutic role of HQ in coronavirus disease-2019 patient, (v) prophylactic use of HQ (vi) side effects and pharamcoguance concern of use of HQ.

2. 4-Aminoquinolines and their anti-viral therapeutics applications:

Hydroxychloroquine and chloroquine are 4-aminoquinoline derivatives. The change in N-diethyl side chain of CQ by N-ethyl hydroxyl group in HQ offers more solubility. Further, HQ showed significant bioavailability and immunomodulatory effects by interfering interleukin-6 synthesis (IL-6) which has essential role in chronic inflammation and auto-immunity [11-13]. Furthermore, HQ produces less toxic metabolites, less adverse effects and hence considered safer drug than CQ [11-14]. Besides this, HQ also displayed anti-viral activity by stimulating the pathway of IFN-β via phosphorylation [11,12]. HQ is primarily an anti-malarial drug which is also used in autoimmune diseases [11-13], sarcoidosis [14], rheumatoid arthritis [15], alopecia areata [16], lupus erythematosus [17], anti-thrombotic [18] and antineoplastic treatment [19]. Moreover, HQ shows potential antiviral activity and therapeutic use against Ebola [20], Marburg [20], Zika [21], HIV-1[22], Dengue [23], Chikungunya [24], Hepatitis C [25], MERS-CoV [26] and SARS-CoV [27] virus treatment.

Various pathways for mechanism of action of HQ are explained against virus [20-27]. Haque et al. [20] proposed that, HQ deposition in the endosome increases the pH and causes inactivation of lysosomal enzymes as well as receptors which inhibits entry of virus. Kumar et al. [21] reported that, HQ activates the innate immune signal pathways and promote the production of reactive oxygen species which inhibit Zika virus cycle. Romaneli et al. [22] mentioned that, HQ may block hydrolysis of polypeptide product and HIV virus replication [22]. Further increasing endosomal pH changes the activity of hydrolases enzyme which inhibits glycoprotein production [22]. Wang et al. [23] found that, HQ activates innate immune signal pathways and interferes mitochondrial viral signalling [23]. Further, HQ induces production of cellular reactive oxygen which imparts in host defence system [23]. Pandya et al. [24] reported that, mechanism of HQ action against Chikungunya virus is still unclear; however it is related to anti-inflammatory response. Chandramohan et al. [25] mentioned that, HQ is responsible for blocking of endocytosis mechanism required for hepatitis C virus entry. Increase in lysosomal pH causes inactivation of lysosomal enzymes which prevent further viral replication. Dyall et al [26] and Yao et al. [27] proposed that, HQ affects entry of virus, increases the pH of endosome. Further, it knocks down the endocytosis process and viral replication phenomenon in corona viruses. Thus HQ plays an important role against various viral infections and hence similar kind of mechanistic role may be expected in case of action of HQ against COVID-19 virus which may needs strong evidences to prove it.

3. Effects of HQ on the immune system and COVID-19:

In case of COVID-19, the lung injury is more obvious in critical patients that are directly linked with a cytokine storm. The pro-inflammatory cytokine storm with a severe illness affected the prognosis. Various IL-6 antibody blockers, convalescent plasma therapies have been applied to offset the cytokine storm. Hence it is predicted that, HQ may be used against COVID-19, considering its antiviral [20-27] and immunomodulatory effects [11-13]. The excessive productions of cytokines lead to obstruct innate immune response [11-13]. The HQ regulates or modulates the production of different cytokines (like IL-6, IL-1, IL-2) which are involved in the cytokine storm [11]. The HQ also displayed anti-viral activity by stimulating the pathway of IFN-β via phosphorylation [11,12]. Further, HQ endorse post-translational adaption of signalling proteins to modulate innate responses and thus it is postulated that, antiviral and immuno-modulatory effects of HQ may synergetically combat the COVID-19 infection [11,12,28]. Besides this, HQ considerably induces cellular production of reactive oxygen radical/species, which shows a significant role in host defence mechanism [11,28]. Thus, it is possible that, HQ may be displaying an emerging role in regulating and alleviating the host innate immunity against COVID-19, however it requires further investigation to confirm the actual role of HQ against COVID-19 considering innate immunity factor [11,12,28].

4. In vitro inhibition of SARS-CoV-2 by HQ and CQ

Recently some reports are available which demonstrated in-vitro [27,29] (Table 1, entries 1-8) and in-vivo [5-10] inhibition of SARS-CoV-2 virus by use of HQ. Liu et al. [29] have studied antiviral effects of HQ and CQ against the SARS-CoV-2 virus infection at various multiplicities of infection (MOI). They measured in vitro cytotoxicity of HQ and CQ in African monkey kidney Vero-E6-cells [29]. They reported 249 and 273 µM CC50 (50% cytotoxic concentration) values for HQ and CQ respectively (Table 1, entries 1,2). Further, EC50 (50 % effective maximal concentration) values was found to be slightly higher for HQ than CQ which indicating lesser potency of HQ over CQ (Table 1, entries 1-4) [29]. Considering the SI (selectivity index), CQ is found to be more potent than HQ (Table 1, entry 1-4). However, author proposed the use of HQ considering the safety and toxicity concern. In context to this, Yao et al. [27] have reported lesser EC50 value for HQ (6.14 and 0.72 µM) than CQ (23.9 and 5.47 µM) at 24 and 48 hours respectively which indicating that HQC may be a more potent and safer drug than CQ to treat COVID-19 by considering in-vitro antiviral activity (Table 1, entry 5-8).
In some cases, viral entry involves endocytosis and subsequent virus replication by increasing the pH level of lysosomes. Thus, HCQ is assumed to affect the viral entry [31].

In some cases virus is transported to endosome and gets replicated in it [32]. These endosome are get ruptured by low pH acidic intracellular lysosome enzymes and leads to relive the viral contents and replicated virons [31]. It is believed that, accumulation of HCQ increases the pH level of endosome as well as Golgi network and interfere functioning of various important acid hydrolases enzymes that hamper synthesis of new protein modification and viral inside-outside entry mechanism [32]. Thus in conclusion, these HCQ changes the pH of cell organelles and inhibit the fusion process of virons, replication, glycosylation of viral proteins, endocytosis, viron transport and viron release [27,29,30-32].

### 5. HCQ: Possible mechanism of action against COVID-19:

Possible mechanism is proposed on the basis of initial assessment of HCQ as a drug against SARS-CoV-2 virus [27,29]. It is postulated that, HCQ functions in three different ways against the SARS-CoV-2 virus [29-33]. Angiotensin-converting enzyme-2 (ACE-2) which was considered as a possible binding receptor for SARS-CoV-2 is also known as a possible receptor for SARS-CoV-2 considering the amino acid homology [30]. It is recognized that, SARS-CoV-2 having 76% amino acid homology to that of SARS-CoV [2,3]. Thus it may be possible that, SARS-CoV-2 virus follows the similar kind of mechanism like SARS-CoV virus to enter into the host-cell [2,3]. SARS-CoV-2 has spike protein which involves the two subunits namely S1 and S2 [2,3,30]. The first S1-subunit is showing binding ability towards receptor ACE-2 (in adipose tissues); whereas, second S2-subunit is involving in membrane fusion and insertion of RNA into the cell [27,29,30]. Various mechanisms have been postulated in the literature about the antiviral action of HCQ which affects the viral entry pathway by decreasing the glycosylation of ACE-2 [27,29,30]. Since, it is assumed that virus binds to ACE-2 receptor to enter inside the host cell. HCQ is a weak base which can be accumulated within acidic organelles (endosome, Golgi vesicles and lysosomes) wherein actual pH is found to be low. After accumulation, the HCQ leads to affect acidic organelles as well as functioning of several acid hydrolase enzymes by increasing the pH of organelles [31]. Some viruses enter by endocytosis mechanism in which virus targets the lysosomes [31]. These lysosomes having low pH and by action of acid hydrolase enzymes viral particles are disrupted which liberates various viral contents (infections material, nucleic acid and enzymes) that required for viral replication [31]. The accumulated HCQ in acidic organelles has been found to hamper the process of endocytosis and subsequent virus replication by increasing the pH level of lysosomes. Thus, HCQ is assumed to affect the viral entry [31].

### Table 1: In vitro inhibition of SARS-CoV-2 virus by hydroxychloroquine and chloroquine

<table>
<thead>
<tr>
<th>Entry</th>
<th>Drug</th>
<th>EC50</th>
<th>CC50</th>
<th>SI</th>
<th>IC50</th>
<th>Time</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chloroquine (0.01 MOI)</td>
<td>2.71</td>
<td>273</td>
<td>100.81</td>
<td>NM</td>
<td>48 h</td>
<td>29</td>
</tr>
<tr>
<td>2.</td>
<td>Hydroxychloroquine (0.01 MOI)</td>
<td>4.51</td>
<td>249</td>
<td>55.32</td>
<td>NM</td>
<td>48 h</td>
<td>29</td>
</tr>
<tr>
<td>3.</td>
<td>Chloroquine (0.02 MOI)</td>
<td>3.81</td>
<td>273</td>
<td>71.71</td>
<td>NM</td>
<td>48 h</td>
<td>29</td>
</tr>
<tr>
<td>4.</td>
<td>Hydroxychloroquine (0.02 MOI)</td>
<td>4.06</td>
<td>249</td>
<td>61.45</td>
<td>NM</td>
<td>48 h</td>
<td>29</td>
</tr>
<tr>
<td>5.</td>
<td>Hydroxychloroquine</td>
<td>6.14</td>
<td>NM</td>
<td>NM</td>
<td>24 h</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Chloroquine</td>
<td>0.72</td>
<td>NM</td>
<td>NM</td>
<td>48 h</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Hydroxychloroquine</td>
<td>23.9</td>
<td>NM</td>
<td>NM</td>
<td>24 h</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Chloroquine</td>
<td>5.47</td>
<td>NM</td>
<td>NM</td>
<td>48 h</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

Unit for EC50 and CC50: µM

Liu et al., [29] have confirmed these in vitro antiviral activity results by immunofluorescence microscopy analysis study which suggested that, HCQ and Q causes blocking of transport of SARS-CoV-2 virus and its genome from co-localization with early endosomes. Further, they assumed blocking of the endocytosis phenomenon due to endosome maturation attributed to change in endosome pH [29]. Thus both authors [27,29], concluded HCQ as a safer and less toxic drug to treat COVID-19 on the basis of in vitro analysis study.

### 6. In vivo inhibition of SARS-CoV-2:

Till date only 9 clinical trials/case study reports are available which indicating the use of HCQ in COVID-19. Some case studies are showing good outcome with the HCQ treatment while some case studies are reporting poor clinical outcome with substantial adverse effects. Chen et al. [5], reported open 1:1 controlled trial study in COVID-19 patients treated with the HCQ which indicated no significant effect of HCQ in treatment of COVID-19 patients compared to that of control group. 33.3% patients from the HCQ group and 46.7% patients from control group showed radiographic progression in follow-up examination (Table 2, entry 1). Throat swab for SARS-CoV-2 was found to be negative for 86.7% and 93.3% cases of HCQ group and control group respectively. Thus, they did not observe any specific distinction in between HQC treatment and conventional treatment for COVID-19. The major limitation of this study is the smaller sample size and lower statistical significance.

A French group Gautret et al. [6] have reported effective use of hydroxychloroquine + azithromycin (HCQ + AZT) in treatment of COVID-19 which cured 100% patients on sixth day whereas, 57% patients were cured virologically by only HCQ treatment on sixth day (Table 2, entry 2). In comparison to this, 12.5% patients were cured virologically in control group on sixth day. The total duration of treatment/medication was ten days. In their report, no specific adverse effects of use of HCQ + AZT are mentioned except one death. This study has several limitations such as small sample size, limited follow-up, exclusion of patients during treatment and specific age group. However, another French group Molina et al., [7] reported no clinical benefit and poor clinical outcome with the synergistic treatment of AZT+HCQ in coronavirus disease-2019 patients (Table 2, entry 3). In their study, nasopharyngeal swab for SARS-CoV-2 virus were found to be positive in 80% patients on fifth day. The major limitation of this report is the absence of control study. Further, they have not reported details of study and statistical significance, since it is a letter to editor.

Chen et al. [8], carried out 1:1 randomized clinical trials
which indicating faster clinical recovery, pneumonia absorption and cough reduction in HCQ treated group as compared to control group (Table 2, entry 4). They showed improvement in pneumonia in 80.6% of HCQ treated patients compared to 54.8% of control group. Standard treatment involves use of oxygen therapy, immunoglobulin, antiviral use, antibacterial use with or without corticosteroids. They proposed that, HCQ acted as a protector for COVID-19 patient due to its antiviral and immunomodulatory effects. Two patients of HCQ treated group showed adverse effects, thus adverse effects needs to be address carefully in the HCQ treated patients. Further in another report of 80 mildly infected patients, Gautret et al. [9] have confirmed potential use of HCQ + AZT therapy for COVID-19 (Table 2, entry 5). In this study, they reported death of one patient, and in whole study they performed ECG in order to understand the detrimental side effects of HCQ + AZT. On fifth day, 97.5% of patients showed negative virus culture from respiratory sample, however, the major limitation of this study is the absence of control group.

Notably, Chorin et al. [10] reported QT prolongation in number of patients due to treatment of HCQ and AZT in between 3-4 days. In this report, 30% of patients showed QT prolongation (> 40 ms), while 11% of patients showed QT increased (> 500 ms) which indicating the high risk arrhythmia (Table 2, entry 6). They reported death of four patients in a set of 94 patients. Tang et al. [33] mentioned use of HCQ against COVID-19 patients. They found that, medication of HCQ results in more alleviation of clinical symptoms than standard of care treatment (Table 2, entry 7). Specifically they mentioned that, viral response not increases but it accelerates the alleviation of clinical symptoms and recovery of lymphopenia. In final conclusion, no difference was observed in the main outcome of the HCQ group and control group. Mahaves et al. [34], carried out routine data analysis of 181 patients which concluded non-supportive use of HCQ for COVID-19 in their study compared to control group (Table 2, entry 8). Further, they found modification in ECG in 9.5% patent treated with HCQ. They reported death of 2.8% and 4.6% patients in HCQ treated and control patient’s group respectively. Moreover, 28.6 % and 24.2 % patients from HCQ and control group showed development of acute respiratory distress syndrome.

Magagnoli et al. [35] reported retrospective analysis of 368 patients which are divided into three categories such as HCQ group, HCQ+AZT group and control group (Table 2, entry 9). They observed higher death ratio in HCQ treated group. They reported the rate of death as 27.8%, 22.1%, and 11.4%, in the HCQ, HCQ+AZT and control group respectively. Further they mentioned that, specific precaution is required for the use of HCQ which may show severe adverse effects. Thus the maximum number of recovery/discharge was from control group and not from HCQ treated group.

Thus in conclusion, there are several dispute in use of HCQ for the treatment of COVID-19. Gautret et al., [6,9] and Chen et al., [8] supported the use of HCQ alone or in combination with antibiotic such as AZT. However, Chen et al., [5] Molina et al., [7] Mahaves et al., [34], Chorin et al., [10] and Magagnoli et al., [35] did not reported any significant effect/clinical outcome of HCQ treatment in their study of COVID-19 treatment. These findings (use of HCQ for COVID-19) are not sufficient to conclude the use of HCQ for COVID-19, thus important results and conclusion for the widespread adoption of HCQ against coronavirus disease-2019 are still waiting. The individual uses of both these (HCQ and AZT) drugs are associated with QT Prolongation [33]. Hence QT prolongation is a major concern by synergetic use of HCQ + AZT in treatment of coronavirus disease-2019 [33]. Thus, there is an urgent need for the further reporting of case studies/clinical trials to get actual insights of clinical outcomes for possible use of HCQ against COVID-19 by considering an increasing widespread use of HCQ as a therapy as well as prophylaxis despite of its detrimental toxic effects. The major limitations of above mentioned studies is small sample size, random trials, short duration, limited follow-up, lack of control and no enrolment of children.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>Treatment and dosage</th>
<th>Control</th>
<th>Observation and general conclusion</th>
<th>Date publish/Preprint</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open 1:1controlled</td>
<td>N = 30 MA = 50.5 and 46.7 TD: 5 days RN: NCT04261517</td>
<td>15 patients: HCQ (400 mg per day for 5 days) + conventional treatments MA = 50.5</td>
<td>15 patients: conventional treatment only MA = 46.7</td>
<td>No major distinction between both groups. One patient from HCQ group becomes severe ill during the treatment. On seventh day, throat swab for SARS-CoV-2 was found to be negative for 86.7% and 93.3% cases of HCQ group and control group respectively. Transient diarrhea and abnormal liver function appeared in 26.7% of the HCQ group and 20% of the control group.</td>
<td>Published 03-Mar-20</td>
</tr>
<tr>
<td>2</td>
<td>Open-label non-randomized clinical trial N = 36 MA = 45 TD = 10 days RN: 2020-000890-25</td>
<td>14 patients: HCQ (600 mg/day for 10 days), MA = 51.2 On day six, 57.1% patients were virologically cured. 6 patients: HCQ (600 mg/day for 10 days)+ AZT (500 mg per day one and then 250 mg per day upto fifth day), MA =</td>
<td>16 patients: On day six, 12.5% patients were virologically cured in the control Use of AZT along with HCQ showed more efficiency for elimination of virus bad Limitation: Major limitation is small sample size, limited follow-up, exclusion and specific age group of patients. Reported death of one patient</td>
<td>Published 20-Mar-20</td>
<td>[6]</td>
<td></td>
</tr>
<tr>
<td>Study Type</td>
<td>N</td>
<td>MA (years)</td>
<td>TD (days)</td>
<td>RN</td>
<td>Patients Details</td>
<td>MA (years)</td>
</tr>
<tr>
<td>----------------------------------</td>
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<td>----------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Observational, non-controlled</td>
<td>11</td>
<td>58.7</td>
<td>10</td>
<td>RN:ChiCTR2000029559</td>
<td>11 patients: Hydroxychloroquin (400 mg/day for 5 days) + standard treatment MA = 45.2</td>
<td>59.2</td>
</tr>
<tr>
<td>Randomized clinical trial</td>
<td>62</td>
<td>44.7</td>
<td>5</td>
<td>RN:ChiCTR2000029868</td>
<td>31 patients: Hydroxychloroquin (400 mg/day for 5 days) + standard treatment MA = 44.1</td>
<td>60</td>
</tr>
<tr>
<td>Uncontrolled non-comparative observational study</td>
<td>80</td>
<td>53</td>
<td>10</td>
<td>RN: 2020_060</td>
<td>80 patients: HCQ (600 mg per day for ten days) + AZT (500 mg on first day and then 250 mg up to fifth day)</td>
<td>45.2</td>
</tr>
<tr>
<td>Retrospective study</td>
<td>84</td>
<td>63</td>
<td></td>
<td></td>
<td>84 patients: HCQ + AZT</td>
<td>63</td>
</tr>
<tr>
<td>Multicenter, open-label, randomized controlled trial</td>
<td>150</td>
<td>46.1</td>
<td>3 weeks</td>
<td>RN: 2020_066</td>
<td>75 patients: HCQ (1200 mg per day for 3 days and then 800 mg per day for 2-3 weeks) MA = 48</td>
<td>60</td>
</tr>
<tr>
<td>Routine collected data</td>
<td>181</td>
<td>60</td>
<td>7</td>
<td></td>
<td>84 patients: HCQ (600 mg/day for 2 days as only mentioned) + Standard care treatment</td>
<td>63</td>
</tr>
<tr>
<td>Retrospective analysis</td>
<td>368</td>
<td>69</td>
<td></td>
<td></td>
<td>97 patients: (HCQ + standard supportive treatment), 113 patients: (HCQ + AZT + standard supportive treatment)</td>
<td>69</td>
</tr>
</tbody>
</table>

N: No. of population (patients), MA: median age in population (years); TD: treatment days, RN: registration number
7. Prophylaxis use of HCQ

Interestingly, HCQ is allowed to use as prophylaxis in order to prevent possible infection of COVID-19 [27,36,37]. Despite several detrimental adverse effects and lack of evidences the questions arises regarding to prophylactic use and dosage of the HCQ. Most recently, dosing study of HCQ is optimized by Yao et al. [27], who reported EC\textsubscript{50} values (for HCQ) of 6.14 and 0.72 \mu M at 24 and 48 hours respectively [27]. On the basis of physiologically-based pharmacokinetic models, dosing of 400 mg BID (on day 1) and 200 mg BID (from day 2 to day 5) offers lung tissue trough concentration 21 and 83 times higher than EC\textsubscript{50} value at day 1 and day 10 respectively [27]. This study may indicated, effective use of HCQ as a prophylactic drug to prevent possible infection of COVID-19 on the basis of model and in-vitro analysis [27]. Moreover, cytokine storm (in COVID-19 infection) may be regulated by immunomodulatory action of HCQ [11-13]. However, looking to contradictory case results of use of HCQ against COVID-19 there is an urgent need for more confirmatory evidences [5-10,33-35].

HCQ may looks a promising life saving drug for in-vitro inhibition of coronavirus, however in practise it failed to reduce the actual effective corona virus load in mice [38]. Thus it is not confirmatory that whatever works in-vitro can be work well in-vivo, hence there is an urgent need to study clinical trials [38-42]. Further sudden increased use of HCQ as a prophylaxis despite of strong effective evidences may faces detrimental side effects and leads to create shortage of HCQ drug [36-38]. More, recently some hospitals of France as well as Sweden have stopped use of HCQ/CQ in clinical case study/practice considering the lack of therapeutic evidences, detrimental side effects and poor clinical outcome [39,40]. It is mentioned by Ferari in media report Health-News that, use of HCQ +AZT sometimes may become more harmful than disease itself [39]. Moreover, recently, a death is reported by self-medicating use of CQ against COVID-19, hence, self-medication as a prophylaxis should be avoided which may be harmful or sometimes may be lethal [41,42]. Prophylaxis use of HCQ should be done after medical (practitioner) advice only. Thus at present, more confirmatory results/study reports are still awaited for prophylaxis use as well as in-vivo clinical use of HCQ to treat COVID-19 [36-42].

8. Pharmacovigillance approach for the use of HCQ:

Literature showing several adverse events associated with the use of HCQ. Although HCQ is less toxic and safer than CQ, still it possesses some detrimental adverse effects which are not negligible and cannot be ignored. In view of pharmacovigilance concern, unnecessary and excess use of the HCQ (without physician advise) may be dangerous which may have several side effects (Table 3, entries 1-6) such as cardiac complications (Table 3, entry 1) [43], ocular side effects (Table 3, entry 2) [44], myopathy, neuropsychiatric effects (Table 3, entry 3) [45], gastrointestinal discomfort (Table 3, entry 4) [46], erythema multiforme, exanthematic pustulosis (Table 3, entry 5) [47], hypoglycaemia (Table 3, entry 6) [48], Stevens-Johnson syndrome (Table 3, entry 5) [49], thrombocytopenia (Table 3, entry 6) [17] and other common side effects such as weight-loss, appetite-loss, dizziness, weakness, nausea, vomiting and allergic reactions etc. (Table 3, entry 6) [50]. Most of these side effects are associated with the long term use.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Adverse effects</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cardiac complications: QT prolongation, ventricular hypertrophy, ventricular arrhythmias, hypokinesia, cardiac arrest, pulmonary arterial hypertension, ventricular arrhythmias, valvular dysfunction, heart failure.</td>
<td>[43]</td>
</tr>
<tr>
<td>2</td>
<td>Ocular side effects: Retinopathy, blurred vision, blindness, corneal deposition</td>
<td>[44]</td>
</tr>
<tr>
<td>3</td>
<td>Neuro/muscular side effects: Signal conduction disorders, convulsion, myopathy, vertigo, psychosis, ataxia, nightmare, depression</td>
<td>[45]</td>
</tr>
<tr>
<td>4</td>
<td>Gastrointestinal side effects: Diarrhoea, vomiting, abdomen cramping, nausea, abnormal liver function</td>
<td>[46]</td>
</tr>
<tr>
<td>5</td>
<td>Cutaneous/allergic side effects: Erythema multiforme, exanthematic pustulosis, Stevens-Johnson syndrome, allergy, rashes.</td>
<td>[47,49]</td>
</tr>
<tr>
<td>6</td>
<td>General major side effects: Thrombocytopenia, hypoglycaemia, obnubilation, weight loss, appetite loss.</td>
<td>[48,50]</td>
</tr>
</tbody>
</table>

Conclusion:

In conclusion, HCQ shows antiviral effects against various viruses, further it’s use showed immunomodulatory effects. HCQ may be safe to use and required in lower dosage than CQ to inhibit viral load, to regulate cytokine storm and time-span of viremia on the basis of in-vitro analysis. However, more clinical trials/ evidences are still awaited and required to prove in-vivo efficacy of HCQ against COVID-19. At present, clinical trials and case studies reported for the use of HCQ to combat COVID-19 showed the contradictory clinical outcome/results. QT prolongation is the major concern when HCQ is combined with drugs which tackle lower respiratory tract infection (e.g. AZT). Adverse effects cannot be neglected in use of HCQ against COVID-19. Thus the use of HCQ (in COVID-19 treatment) is of current international interest, although a consensus has not yet been reached. Extreme care is required for the HCQ treatment in pregnant women, pediatric patient and patient with comorbidity in coronavirus disease COVID-19. Misuse of HCQ as a prophylaxis of COVID-19 (without physician’s advise) should be avoided due to lack of strong evidences which may results into one or more detrimental side effects. Use of HCQ should be done after medical advice only. Considering
pharmacovigilance and public health concern, NO self-medication of HCQ is advisable under any circumstances which may be risky and sometimes lethal. Thus the present review discussed the possible anti-viral mechanism of HCQ, prophylaxis strategy and effect of HCQ against SARS-CoV-2 virus in vitro study. Further this review also summarizes and debates all available clinical trials/case studies of HCQ use against COVID-19 (with clinical outcome). Finally possible detrimental adverse effects are also discussed considering the public health and pharmacovigilance concern.

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Note for readers: Readers must refer cited research article(s) for more detail information. Clinical treatment should NOT be based on this review article.

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