Real-life experience of ledipasvir and sofosbuvir for HCV infected Korean patients: a multicenter cohort study

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Conclusion
LDV/SOF is effective and safe for treating HCV-infected Korean patients with high SVR12 rates.
Background/Aims: To evaluate the efficacy and safety of ledipasvir/sofosbuvir (LDV/SOF) therapy in hepatitis C virus (HCV)-infected Korean patients in a real clinical setting.

Methods: A total of 273 patients who received LDV/SOF therapy between May 2016 and February 2021 were consecutively enrolled and analyzed. A per-protocol analysis was performed to evaluate the virologic response.

Results: Seventy-five percent were infected with genotype 1, and 25% were infected with genotype 2. A hundred eighty-one (66.3%) patients had chronic hepatitis, 74 (27.1%) had compensated cirrhosis, eight (2.9%) had decompensated cirrhosis, and 10 (3.7%) had undergone liver transplantation. Undetectable HCV RNA at week 4 was achieved in 90.2% (231/256) of patients, 99.2% (250/252) achieved the end of treatment response, and 98.1% (202/206) achieved sustained virologic response at 12 weeks post-treatment (SVR12). According to liver function, the SVR12 rates were 99.3% (135/136) in chronic hepatitis, 96.4% (53/55) in compensated cirrhosis, and 100% (6/6) in decompensated cirrhosis. The SVR12 rates according to the genotype were 98.2% (167/170) for genotype 1 and 97.2% (35/36) for genotype 2. An 8-week LDV/SOF treatment in treatment-naive chronic hepatitis patients with HCV RNA < 6,000,000 IU/mL at baseline resulted in 100% (23/23) SVR12 rates. Overall, LDV/SOF was tolerated well, with a 0.7% (2/273) discontinuation rate due to adverse events that were unrelated to LDV/SOF.

Conclusions: LDV/SOF is effective and safe for treating HCV-infected Korean patients with high SVR12 rates.

Keywords: Hepatitis C virus; Sofosbuvir; Ledipasvir; Sustained virologic response; Genotype
units of eight hospitals of the Catholic University of Korea between May 2016 and February 2021 were consecutively enrolled. Eligible patients were 18 to 70 years old with chronic HCV infection documented based on positive HCV RNA results, irrespective of LC and treatment history of HCV. Patients who were positive for hepatitis A, B, or human immunodeficiency virus and viable HCC at enrollment were excluded from the study. This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Institutional Review Board of the Catholic University of Korea (XC22RIDI0001). Written informed consent by the patients was waived due to a retrospective nature of our study.

**Treatment**

Patients with GT1, 2, 4, 5, and 6 received a fixed-dose combination of LDV/SOF (LDV, 90 mg; SOF, 150 mg) once daily for 12 weeks regardless of cirrhosis status, according to the guidelines [5,20]. In GT1 patients with decompensated LC, liver transplantation (LT), or treatment-experienced compensated LC, additional weight-based ribavirin was administered at a total daily dose of 1,000 or 1,200 mg for patients weighing < 75 or ≥ 75 kg, respectively. Since June 2018, 8 weeks of LDV/SOF treatment was approved in Korea and administrated to treatment-naïve patients with GT1, whose HCV RNA level was < 6 million IU/mL.

**Clinical and laboratory data**

The following baseline clinical and laboratory data of all included patients were collected at the start of the treatment: sex, age, complete blood count, aspartate transaminase (AST), alanine transaminase (ALT), total bilirubin, albumin, prothrombin time, history of HCC, treatment history of HCV infection, presence of LC with or without decompensation, diabetes, hypertension, and chronic kidney disease (CKD), which was defined as stage 3 or worse (estimated glomerular filtration rate < 60 mL/min/1.73 m²). Serum HCV RNA levels were quantified using a COBAS TaqMan HCV quantitative test version 2.0 (lower limit of quantification [LLOQ], 15 IU/mL; Roche Molecular Systems, Branchburg, NJ, USA). The HCV GT was determined using the gene sequencing assay. The presence of LC was based on liver biopsy, transient elastography (FibroScan, Echosens, Paris, France), and/or imaging studies using sonography, computed tomography, and magnetic resonance imaging [22]. Laboratory tests, including AST, ALT, and HCV RNA levels, were performed at 4 weeks, end of treatment (EOT), and 12 weeks after EOT.

**Outcomes**

The primary outcome was the rate of SVR, defined as the proportion of patients with HCV RNA concentration lower than the LLOQ 12 weeks after EOT (SVR12) by per-protocol (patients receiving ≥ 1 dose of DAA with available HCV RNA data at post-treatment week 12). The secondary outcomes were the rate of rapid virologic response (RVR), EOT response (ETR), and SVR12 according to the GT, prior treatment status, treatment period in treatment-naïve GT1 patients with HCV RNA < 6 million IU/mL, presence of LC, and comorbidities. RVR and ETR were defined as undetectable HCV RNA at EOT and 4 weeks, respectively. We also monitored any adverse events (AEs) during LDV/SOF treatment, including severe AEs leading to permanent discontinuation of LDV/SOF or ribavirin.

Table 1. Baseline characteristics of the study population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total patients (n = 273)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>60 (24–88)</td>
</tr>
<tr>
<td>Male sex</td>
<td>107 (39)</td>
</tr>
<tr>
<td>HCV RNA, IU/mL</td>
<td>868,000 (34–47,160,902)</td>
</tr>
<tr>
<td>GT1/GT2/GT4</td>
<td>204/68/1 (74.7/25/0.3)</td>
</tr>
<tr>
<td>AST, U/L</td>
<td>49 (14–314)</td>
</tr>
<tr>
<td>ALT, U/L</td>
<td>42 (10–432)</td>
</tr>
<tr>
<td>Chronic hepatitis</td>
<td>181 (66.3)</td>
</tr>
<tr>
<td>Compensated cirrhosis</td>
<td>74 (27.1)</td>
</tr>
<tr>
<td>Decompensated cirrhosis</td>
<td>8 (2.9)</td>
</tr>
<tr>
<td>PSLT</td>
<td>10 (3.7)</td>
</tr>
<tr>
<td>History of HCC</td>
<td>10 (3.7)</td>
</tr>
<tr>
<td>Prior HCV therapy</td>
<td></td>
</tr>
<tr>
<td>Treatment-naïve</td>
<td>243 (89.0)</td>
</tr>
<tr>
<td>IFN-experienced</td>
<td>27 (9.9)</td>
</tr>
<tr>
<td>DAA-experienced</td>
<td>3 (1.1)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>54 (19.8)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>90 (33.0)</td>
</tr>
<tr>
<td>CKD stage 3–5</td>
<td>27 (9.9)</td>
</tr>
</tbody>
</table>

Values are presented as median (range) or number (%). HCV, hepatitis C virus; GT, genotype; AST, aspartate aminotransferase; ALT, alanine aminotransferase; PSLT, post-state liver transplantation; HCC, hepatocellular carcinoma; IFN, interferon; DAA, direct-acting agent; CKD, chronic kidney disease.
Statistical analysis
Continuous variables are documented as mean ± standard deviation or median and range. Categorical variables are expressed as counts with percentages. Differences between categorical variables were analyzed using the chi-square test or Fisher’s exact test. For continuous variables, Student’s t test or the Mann-Whitney U test was performed to analyze the group differences, as appropriate. Statistical significance was set at a two-tailed p value of < 0.05. All statistical analyses were performed using R version 4.0.4 (http://cran.r-project.org) and Prism standard version 8.4.2 (GraphPad Software, San Diego, CA, USA).

RESULTS
Baseline characteristics
Among the 273 patients enrolled between May 2016 and February 2021, 206 patients (75.5%) completed the follow-up for 12 weeks after EOT, with HCV RNA results available for assessing SVR12. The baseline patient characteristics are summarized in Table 1. The median age was 60 years (range, 24 to 88) and 107 (39.0%) patients were male. Most patients were infected with GT1 (n = 204, 74.7%) followed by GT2 (n = 68, 24.9%), and were treatment-naïve (n = 243, 89.0%) at baseline. A total of 181 patients...
(66.3%) had chronic hepatitis, and 74 patients (27.1%) had compensated LC at baseline. Among clinical comorbidities before LDV/SOF treatment, hypertension (n = 90, 33.0%) was the most prevalent comorbidity followed by diabetes (n = 54, 19.8%) and CKD (n = 27, 9.9%).

**Efficacy**

Among the 206 patients who were followed up for 12 weeks after EOT, 202 patients (98.1%) successfully achieved SVR12 (Fig. 1A). The rate of RVR in 256 patients was 90.2% (n = 231). ETR was evaluated in 252 patients who completed LDV/SOF treatment, and 250 patients (99.2%) showed ETR in our study. The reasons for patients being unable to evaluate SVR12 (n = 67) were loss to follow-up (n = 65, 97%) and discontinuation of treatment due to AEs (n = 2, 3.0%).

The rate of SVR12 was also evaluated according to the GT and prior treatment status (Fig. 1B). First, the SVR12 rate was not significantly different between GT1 (n = 170) and GT2 (n = 36) (98.2% vs. 97.2%, p = 0.539) patients. The effectiveness of LDV/SOF treatment was both high in treatment-naïve (n = 178) and treatment-experienced (n = 28) patients without significant group differences (98.3% vs. 96.4%, p = 0.445).

We analyzed the efficacy of LDV/SOF in relation to the treatment duration. Among the 204 patients with GT1, 60 patients (29.4%) were treatment-naïve patients with HCV RNA levels < 6 million IU/mL, who could be treated with LDV/SOF for 8 or 12 weeks. Of the 60 patients, 56 patients (8 weeks of treatment, n = 23; 12 weeks of treatment, n = 33) were evaluated for achieving SVR12, and the SVR12 rate was 100% in both groups (p = 1.000) (Fig. 2A).

The treatment effectiveness of LDV/SOF according to the presence or absence of cirrhosis was also evaluated (Fig. 2B). Regardless of cirrhosis status, all patient groups had SVR12 rates above 95%, with results of 99.3% (135/136) and 96.4% (53/55) in patients with chronic hepatitis and compensated cirrhosis (p = 0.200), respectively. All six patients with decompensated cirrhosis reached SVR12; among the nine patients who underwent LT, eight (88.9%) could achieve SVR12 after treatment with LDV/SOF.

Regarding patients with comorbidities, the SVR12 rate was 97.6% among patients with diabetes (n = 41) and 97.0% among those with hypertension (n = 66) (Fig. 2C). Patients with CKD (n = 20) also showed a high SVR rate (100%), and there were no statistically significant differences in the SVR rate according to the type of comorbidity (p = 1.000).

**Virologic failure**

Among 273 included patients, four (1.5%) showed virologic failure after LDV/SOF treatment (Supplementary Table 1). Of four patients showing virologic failure, three were treatment-naïve and the other was interferon (IFN)-experienced. One treatment-naive patient with GT2 did not have LC and showed non-response at 4 weeks treatment with an increase in HCV RNA. The other two treatment-naïve patients had compensated LC with GT1, which resulted in virologic failure, including one patient who achieved ETR. The other patient, who underwent LT and was IFN-experienced, had a high level of initial HCV RNA (9,116,410 IU/mL) and showed virologic relapse at 12-week post-treatment after an achievement of ETR. Among the four patients showing virologic failure, one was successfully treated with glecaprevir/pibrentasvir and the other three were waiting for approval of potent regimens such as SOF/velpatasvir/voxilaprevir in Korea.

**Safety**

During the treatment with LDV/SOF, 33 of all the patients (12.1%) experienced AEs. The most common AEs was fatigue, followed by headache, abdominal discomfort, anemia due to ribavirin, upper respiratory tract infection, rash, and heart failure due to underlying severe aortic stenosis, which occurred in nine (3.3%), seven (2.6%), seven (2.6%), five (1.8%), three (1.1%), one (0.4%), and one patient (0.4%), respectively (Table 2).

Among the 33 patients experiencing AEs, only two (0.7%)
discontinued the treatment due to AE. One patient was an 83-year-old man without LC, who developed severe aortic stenosis. He died due to heart failure related to aortic stenosis after 7 weeks treatment with LDV/SOF. The other patient was a 64-year-old woman with decompensated LC. She discontinued LDV/SOF plus ribavirin treatment after 4 weeks treatment due to anemia and general weakness. The other 14 patients continued LDV/SOF treatment, managing their AEs successfully. Consequently, none of the patients discontinued the treatment because of AEs related to LDV/SOF.

**DISCUSSION**

To the best of our knowledge, this multicenter cohort study is the first to evaluate the efficacy and safety of LDV/SOF for HCV treatment in a real-world setting in South Korea. Overall, the SVR12 rate of LDV/SOF treatment was very high, with a low occurrence of AEs. LDV/SOF treatment consistently demonstrated high rates of SVR12 irrespective of GT, cirrhosis, or comorbidities. Treatment for 8 weeks with LDV/SOF also showed a high SVR12 rate in treatment-naïve GT1 patients whose HCV RNA level was < 6 million IU/mL. Thus, our results suggest that LDV/SOF treatment is effective and safe for treating HCV patients in a real-world setting in South Korea, a country with a high prevalence of GT1 and GT2.

Similar to the promising results of LDV/SOF, including a phase IIIb study in Korea [18], the LDV/SOF treatment showed a 98.1% SVR rate in the real-world setting in our study. The high rate of SVR over 95% sustained regardless of the GT and previous treatment history supporting the HCV treatment guidelines of the KASL [20]. The high efficacy of LDV/SOF in GT1 was well evaluated in previous studies, and the SVR rate of 98.2% in our study is comparable to those of previous studies [23-25]. However, there has been limited real-world data regarding the efficacy of LDV/SOF in GT2. Our multicenter cohort study revealed that, for the first time in Korea, 12-week LDV/SOF treatment in GT2 had a high SVR rate of 97.2%, which is similar to that obtained in previous clinical trials [19]. Based on our results, LDV/SOF could be used equally effectively in not only GT1 patients but also GT2 patients. Moreover, prior HCV treatment experience, especially IFN-based therapy, did not affect the SVR12 rate of the LDV/SOF treatment, supporting the notion that LDV/SOF could be used regardless of the treatment history [17,26].

One of the key findings emerging from our real-world study is the consistent efficacy of LDV/SOF, especially in the 8-week treatment for selected patients and patients with decompensated LC. Based on a post hoc analysis of the ION-3 study, the efficacy of the 8-week regimen of LDV/SOF was compared with a 12-week treatment in treatment-naïve GT1 patients with HCV RNA levels < 6 million IU/mL. Similar to the 12-week treatment, the 8-week treatment with LDV/SOF in selected patients showed a high SVR12 rate (95% to 96%) [27-31], which is in accordance with our results. These results provide an insight into the reduction in the economic burden with short treatment duration, while simultaneously preserving high efficacy. Moreover, LDV/SOF treatment with or without ribavirin demonstrated a high SVR12 rate in compensated and decompensated LC. Although there were few patients with decompensated LC in our study, high SVR12 rates in both compensated and decompensated LC support the treatment guidelines of KASL and previous studies [20,32]. As glecaprevir/pibrentasvir is contraindicated for decompensated LC and SOF/velpatasvir, an effective DAA for decompensated LC [33], is still not approved in South Korea, our promising results of LDV/SOF plus ribavirin in decompensated LC provide the possibility of successful HCV treatment in these Korean patients.

As recurrent HCV infection after LT can lead to graft loss and death [34], successful HCV treatment is an important tool for LT patients with HCV infection. In accordance with the results of previous studies showing a high SVR12 rate (96% to 98%) [35,36], our study also documented a high SVR rate (89%) in post-LT patients. Moreover, a 12-week treatment with LDV/SOF in patients with comorbidities, such as diabetes, hypertension, or CKD, also demonstrated an SVR12 rate of 97% to 100% in our study. Indeed, more than 30% of the patients in our cohort had comorbidities, suggesting the presence of concomitant drugs during HCV treatment. Consequently, the high SVR rate in these patients might be attributable to fewer drug-drug interactions between the concomitant medication and LDV/SOF [25,37]. In addition, an increase in toxicity associated with IFN-based therapy made it challenging to treat HCV infection in patients with CKD. However, LDV/SOF treatment demonstrated a high SVR12 rate even in patients with CKD in our study, similar to the results of previous studies [38-40]. Therefore, the high efficacy of LDV/SOF irrespective of the GT, cirrhosis, LT, and comorbidities make it possible to eradicate HCV infection in
Korea. Despite the high SVR12 rate of LDV/SOF treatment, patients showing virologic failure after LDV/SOF therapy can be treated with SOF/velpatasvir/voxilaprevir or glecaprevir/pibrentasvir according to the treatment guidelines of the KASL and the American Association for the Study of Liver Diseases [20, 41].

In addition to the high efficacy of LDV/SOF, it is important to evaluate the safety of LDV/SOF in real practice. During the LDV/SOF treatment, only 12.1% of the entire population experienced AEs in our study. Among these AEs, fatigue, headache, and abdominal discomfort were the main ones, which were not severe enough to cause discontinuation of LDV/SOF. Moreover, only 0.7% of the patients discontinued treatment unrelated to LDV/SOF. These AE profiles were similar to those in previous studies showing good safety profiles irrespective of cirrhosis, comorbidities, or treatment history [13, 15, 29]. Consequently, 8 or 12 weeks of LDV/SOF might be a safe regimen for HCV patients in a real-world setting in Korea.

This study has several limitations. First, this study was retrospective in nature. Second, the number of patients included in the subgroups, such as the decompensated LC and LT groups, was small. Third, the long-term SVR and clinical outcomes of SVR12 were not analyzed in our study. Because of the retrospective design of our study, there have also been inevitable difficulties in collecting data regarding AEs during LDV/SOF treatment, which contributed to the low AE rate seen in our study. However, to the best of our knowledge, this study is the first to evaluate real-world data of LDV/SOF with the largest number of patients in South Korea. Although the patients with decompensated LC or LT included were small, our results could provide a rationale for treating those patients with LDV/SOF. However, further studies are required with a larger sample size. Moreover, the small number of patients with a history of HCC was due to these patients not being covered under the Korean national health insurance. In the future, further studies with long-term follow-up are necessary to evaluate long-term SVR and its effects.

In conclusion, LDV/SOF in clinical practice in Korea showed high efficacy and good safety profile regardless of the GT, prior treatment status, LC status, LT, and comorbidities. Our study also proved the effectiveness of LDV/SOF in GT2 and in decompensated patients. Moreover, the promising treatment outcomes of the 8-week LDV/SOF treatment in selected patients might decrease the economic burden of HCV treatment in Korea. Therefore, LDV/SOF could be an effective treatment option for HCV infection especially in GT1 and 2 prevalent areas where the use of SOF/velpatasvir is not possible. Consequently, these encouraging results provide insights into the increased possibility of successful HCV eradication in South Korea.

KEY MESSAGE

1. In Korean real-world data, ledipasvir/sofosbuvir (LDV/SOF) treatment showed high rates of sustained virologic response at 12 weeks after treatment (SVR12) regardless of genotype 1 or 2, previous treatment status, underlying liver function and co-morbidities.
2. LDV/SOF also demonstrated consistent efficacy after 8-week treatment in treatment-naïve genotype 1 non-cirrhotic patients with hepatitis C virus RNA levels < 6 million IU/mL.
3. LDV/SOF treatment showed high tolerability with low rates of adverse events during treatment.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

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**Supplementary Table 1. Characteristics of patients who experienced virologic failure after ledipasvir/sofosbuvir treatment**

<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>Liver status</th>
<th>Genotype</th>
<th>Treatment history</th>
<th>Baseline HCV RNA</th>
<th>HCV RNA (4 wk)</th>
<th>HCV RNA (EOT)</th>
<th>HCV RNA (12 wk post-Tx)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/F</td>
<td>CH</td>
<td>2a</td>
<td>Naive</td>
<td>8,588</td>
<td>25,191</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>85/M</td>
<td>cLC</td>
<td>1b</td>
<td>Naive</td>
<td>77,185</td>
<td>0</td>
<td>0</td>
<td>6,637</td>
</tr>
<tr>
<td>64/M</td>
<td>cLC</td>
<td>1b</td>
<td>Naive</td>
<td>299,115</td>
<td>-</td>
<td>112,960</td>
<td>340,383</td>
</tr>
<tr>
<td>56/F</td>
<td>LT</td>
<td>1b</td>
<td>IFN-exp.</td>
<td>9,166,410</td>
<td>0</td>
<td>0</td>
<td>4,421,175</td>
</tr>
</tbody>
</table>

HCV, hepatitis C virus; EOT, end of treatment; Tx, treatment; CH, chronic hepatitis; cLC, compensated liver cirrhosis; LT, liver transplantation; IFN-exp., interferon-experienced.