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ORIGINAL ARTICLE

Short interferon and ribavirin treatment for HCV genotype 2 or 3 infection: NORDynamIC trial and real-life experience

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ABSTRACT

Objective: Interferon-free therapy for hepatitis C virus (HCV) infection is costly, and therefore patients with advanced fibrosis are prioritized. Although coupled with considerable side effects, a large proportion of genotype 2/3 infected patients achieve a sustained virological response (SVR) following interferon-based therapy. The present study evaluates experimental clinical trial and verifying real-life data with the aim of identifying patients with a high likelihood of favorable outcome following short interferon-based treatment. **Material and methods:** The impact of established response predictors, e.g. age, *ITPA* and *IL28B* genetic variants, IP-10, liver histopathology and early viral kinetics on outcome was evaluated among HCV genotype 2/3 infected patients enrolled in the NORDynamIC trial. Similarly outcome was evaluated among Finnish and Swedish real-life genotype 2/3 infected patients treated for 12–16 weeks in accordance with national guidelines. **Results:** In the NORDynamIC trial, age <40 years or achieving HCV RNA <1000 IU/mL day 7 were highly predictive of favorable outcome following 12 weeks therapy. Among 255 Finnish real-life patients below the age of 40 years treated for 12 weeks with interferon and ribavirin, 87% of HCV genotype 2 and 79% of genotype 3 infected patients achieved SVR, and among 117 Swedish real-life patients treated for 12–16 weeks, 97% of HCV genotype 2 and 94% of genotype 3 infected achieved SVR. **Conclusions:** Short interferon-based therapy offers a high likelihood of achieving SVR for selected HCV genotype 2/3 infected patients, and is an acceptable option given that a thorough discussion of the side effects is provided prior to initiation.

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Introduction

Recently major improvements in efficacy and side effects have been reported regarding treatment for hepatitis C virus (HCV) infection following the introduction of direct antiviral agents (DAAs) [1–4]. This holds true especially for HCV genotype 1, 2 and 4 infections, where interferon-sparing regimens yield high rates of sustained virological response (SVR) with side effect profiles often compatible with placebo. However, with regards to treatment of HCV genotype 3 infection, outcome following DAA-based therapy thus far surprisingly has been poorer. When given 12 weeks of sofosbuvir and ribavirin therapy, significantly lower SVR rates were achieved among patients infected

with HCV genotype 3 as compared with genotype 2, both among treatment-naïve as well as treatment experienced patients [1,2]. These SVR rates were augmented upon prolongation of treatment duration, but despite 24 weeks of sofosbuvir and ribavirin, only 60% (27 of 45) of treatment-experienced cirrhotic genotype 3 infected patients achieved SVR [5]. When genotype 3 infected cirrhotic patients were treated for 12 weeks with daclatasvir and sofosbuvir without the addition of ribavirin in the phase III ALLY-3 study, only 70% (21 of 30) achieved undetectable HCV RNA four weeks after discontinuation of therapy, i.e. SVR4, in contrast to 94%

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(112 of 119) of non-cirrhotic patients [6], and relapse also has been documented despite extension of this therapy to 24 weeks and documented adherence [4]. Similarly, when genotype 3 infected treatment-experienced cirrhotic patients were treated with ledipasvir, sofosbuvir and ribavirin for 12 weeks, 73% achieved SVR12 as compared to 89% of patients without cirrhosis [7].

Although the introduction of interferon-free treatment regimens have entailed considerable improvements, on a global perspective, health economics likely will mandate the continued use of interferon-based therapy as a therapeutic option for several years to come, especially for patients with less advanced liver fibrosis, even in more affluent regions [8]. Currently these patients are not prioritized for DAA-based therapy, and often are left waiting for possible future reductions in treatment cost, or progression of fibrosis that would merit therapeutic intervention. It is important to bear in mind that approximately 80% of HCV genotype 2 or 3 infected patients achieve SVR following 24 weeks of therapy with pegylated interferon- α (pegIFN- α) and ribavirin combination therapy [9], albeit with considerable side effects which hampers adherence.

Generally a larger proportion of patients will tolerate interferon-based combination therapy for 12 rather than 24 weeks [10]. In the previously reported NORDynamIC trial, with 13% of enrolled patients having liver biopsy verified cirrhosis, 56% of genotype 2 and 58% of genotype 3 infected treatment-naïve patients achieved SVR following 12 weeks of therapy with pegIFN- α 2a 180 μ g weekly and ribavirin 800 mg daily [10]. When restricting this analysis to patients younger than 40 years, 80% achieved SVR following 12 weeks of therapy [10]. These findings subsequently have been incorporated into the Finnish HCV treatment guidelines [11], where patients infected with HCV genotype 2 or 3 below the age of 40 years are recommended 12 weeks of interferon and ribavirin combination therapy, whereas patients 40 years or above are offered therapy for 24 weeks.

Aside from age below 40, in the NORDynamIC study, achieving HCV RNA <1000 IU/mL by day 7, i.e. immediately prior to the second dose of peg-IFN, entailed achieving SVR in 92% patients treated for 12 weeks (ITT-analysis), and was superior to undetectable HCV RNA week 4, i.e. rapid virological response (RVR), for predicting favorable outcome [10,12,13]. Consequently both of these two favorable response factors, i.e. age below 40 or HCV RNA below 1000 IU/mL day 7, have been incorporated into the Swedish HCV treatment guidelines [14] as suitable for selection of potential candidates for shortened treatment duration, i.e. 12–16 weeks, among genotype 2 or 3 infected patients, provided that no dose reductions are required and RVR is achieved.

Recently, variants of the inosine triphosphate pyrophosphatase (ITPase) gene (*ITPA*), which protect against ribavirin-induced hemolytic anemia during therapy for HCV [15], were reported to be significantly associated with a ribavirin-like reduction of relapse risk in the setting of the abovementioned NORDynamIC study [16,17]. Subsequently this association between *ITPA* variants and SVR also has been reported among HCV genotype 1–4 infected patients treated with higher ribavirin doses [18].

The aim of the present study was to perform a post-hoc, re-evaluation of the potential clinical utility of combinations of favorable response predictors, including the recently reported *ITPA* variants, following 12 weeks of interferon and ribavirin therapy for treatment-naïve patients with chronic HCV genotype 2 or 3 infection in the experimental phase III NORDynamIC trial ($n = 382$), analyzing the results for HCV genotypes 2 and 3 infected patients separately instead of together as previously reported [10], as well as verifying the therapeutic outcome among real-life Finnish and Swedish HCV genotype 2 or 3 infected patients treated with short duration interferon-based therapy in accordance with respective national guidelines. The goal of this assessment was to identify HCV genotype 2 or 3 infected patients with a high likelihood of achieving SVR following a shorter course of interferon-based therapy, as patients with mild fibrosis currently are not candidates for significantly more costly interferon-free, DAA-based therapy.

Materials and methods

Patients

NORDynamIC

Three hundred and eighty-two treatment naïve HCV genotype 2 or 3 infected patients were included in a phase III, open label, randomized, multicenter, investigator-initiated trial (NORDynamIC) conducted at 31 centers in Denmark, Finland, Norway, and Sweden [10]. All patients were adults with compensated liver disease and had detectable HCV RNA. At study entry, patients were randomized to either 12 or 24 weeks of treatment with 180 μ g of peg-interferon α -2a once weekly and 800 mg/day ribavirin. Patients having received at least 80% of the target dose of peg-interferon as well as at least 80% of the target dose of ribavirin for at least 80% of the target treatment duration ($n = 285$), were defined as constituting the per-protocol (PP) population. Adherence was monitored both by reporting of dose reductions and missed doses in the case report forms (CRF) and in the patient diaries in which patients recorded each dosing. The two patients enrolled who

were simultaneously infected with both HCV genotypes 2 and 3 were excluded from this study, as HCV genotypes 2 and 3 were analyzed separately.

Real-life patients in Finland

Between January 2007 and December 2013, 115 HCV genotype 2 infected and 333 HCV genotype 3 infected patients were treated with pegIFN and 800 mg daily dosing of ribavirin at Helsinki University Hospital. Patients below the age of 40 years received 12 weeks of therapy unless they had unfavorable prognostic factors e.g. pronounced steatosis, obesity, metabolic syndrome or cirrhosis. Patients older than 40 years, and those unfavorable pretreatment prognostic factors were treated for 24 weeks.

Real-life patients in Sweden

An inquiry was initially performed among tertiary treatment centers in Sweden, and seven centers (Gothenburg, Karlstad, Gävle, Borås, Skövde, Trollhättan and Halmstad) reported that they had offered a total of 32 HCV genotype 2, and 85 HCV genotype 3 infected patients short course treatment as of December 2013. These patients were selected on the basis of age below 40 years and/or achieving HCV RNA below 1000 IU/mL day 7. One center (Halmstad) prescribed 800 mg daily dosing of ribavirin, and the remaining six centers used 11 mg/kg per day dosing. Two centers (Gothenburg and Karlstad) treated patients for 12 weeks, whereas the remaining five gave most often 12 or on rare occasions 16 weeks of therapy.

The NORDynamIC-study patients

ITPA genotyping methods

SNPs were determined in plasma by allelic discrimination using TaqMan SNP Assays (Life Technologies, Carlsbad, CA): Assay ID C_29168507_10 for *rs7270101*, and C_27465000_10 for *rs1127354*. Both SNPs were in Hardy–Weinberg equilibrium.

Classification of predicted ITPase activity

This was achieved based on the compound genotype of *rs1127354* and *rs7270101* as previously determined by biochemical analyses [19–21] (detailed in Table I), i.e. 100% (CC_{*rs1127354*} AA_{*rs7270101*}), 60% (CC_{*rs1127354*} AC_{*rs7270101*}), 30% (CC_{*rs1127354*} CC_{*rs7270101*}), 25% (CA_{*rs1127354*} AA_{*rs7270101*}), 10% (CA_{*rs1127354*} AC_{*rs7270101*}) and <5% (AA_{*rs1127354*} AA_{*rs7270101*}).

IL28B genotyping

DNA samples were genotyped for the rs12979860 polymorphism with TaqMan SNP genotyping assays (Applied Biosystems Inc., Foster City, CA), using the ABI 7500 Fast real time thermocycler, according to manufacturers recommended protocols. TaqMan probes and primers were designed and synthesized by Applied Biosystems Inc.

IP-10 quantification in plasma

Quantification of IP-10 was performed using Quantikine (R&D SYSTEMS, Minneapolis, MN), a solid-phase ELISA, on plasma samples obtained during the week prior to the start of therapy. All samples were stored at -70°C until assayed.

HCV RNA quantification

Plasma HCV RNA was determined using Cobas AmpliPrep/COBAS TaqMan HCV Test (Roche Diagnostics, Branchburg, NJ), which quantifies HCV RNA with a limit of detection of 15 IU/mL. Quantification was performed on days 0, 3, 7, 8, 29, week 8, week 12, week 24 and 24 weeks after completion of therapy. All samples were frozen (-70°C) and centrally analyzed. Patients were classified as achieving SVR if plasma HCV RNA was undetectable 24 weeks after completion of therapy.

Liver biopsies

Liver biopsies were obtained from all patients within 24 months prior to study entry. The evaluation was performed in a blinded fashion according to the Ishak protocol [22]. Additionally steatosis was graded [23].

Statistical methods

All statistical analyses were performed by SN using IBM SPSS statistics version 19.0 software package (IBM Corporation, Somers, NY). All reported *p*-values are two-sided, and *p*-values <0.05 were considered significant.

Ethical considerations

Written informed consent was obtained from each participating patient, and ethics committees in each participating country approved the NORDynamIC study. The study has been registered at the NIH trial registry (ClinicalTrials.gov Identifier: NCT00143000). Ethics committees in Gothenburg, Sweden, and Helsinki, Finland

Table I. Sensitivity, specificity, positive and negative predictive values of various markers on the likelihood of achieving SVR in patients with HCV genotype 2 ($n = 50$) and genotype 3 ($n = 111$) included in the per-protocol analysis treated for 12 weeks.

| | Genotype 2 Sensitivity | Genotype 3 Specificity | PPV | NPV | Sensitivity | Specificity | PPV | NPV |
|---|---------------------------|---------------------------|-----------------|----------------|----------------|-----------------|----------------|-----------------|
| Age <40 years 41% of patients (66/161) | 31% (9/29) | 95% (20/21) | 90% (9/10) | 50% (20/40) | 64% (47/73) | 76% (29/38) | 84% (47/56) | 53% (29/55) |
| ITPase activity <100% 35% of patients (54/154) | 57% (16/28) | 90% (18/20) | 89% (16/18) | 60% (18/30) | 38% (26/69) | 73% (27/37) | 72% (26/36) | 39% (27/70) |
| <i>IL28B</i> genotype (CC vs. CT/TT) 47% of patients (74/157) | 54% (15/28) | 43% (9/21) | 55% (15/27) | 41% (9/22) | 44% (31/70) | 58% (22/38) | 66% (31/47) | 36% (22/61) |
| Non-significant fibrosis (Ishak stage 0–2) 50% of patients (74/149) | 46% (13/28) | 58% (11/19) | 62% (13/21) | 42% (11/26) | 65% (42/65) | 70% (26/37) | 79% (42/53) | 53% (26/49) |
| Non-cirrhosis (Ishak stage 0–4) 90% of patients (134/149) | 93% (26/28) | 21% (4/19) | 63% (26/41) | 67% (4/6) | 97% (63/65) | 19% (7/37) | 68% (63/93) | 78% (7/9) |
| No steatosis (Steatosis grade 0) 38% of patients (57/149) | 64% (18/28) | 58% (11/19) | 69% (18/26) | 52% (11/21) | 35% (23/65) | 78% (29/37) | 74% (23/31) | 41% (29/71) |
| IP-10 baseline <150 pg/mL 44% of patients (66/151) | 36% (10/28) | 47% (9/19) | 50% (10/20) | 33% (9/27) | 51% (35/69) | 69% (24/35) | 76% (35/46) | 41% (24/58) |
| IP-10 baseline <600 pg/mL 91% of patients (138/151) | 93% (26/28) | 11% (2/19) | 60% (26/43) | 50% (2/4) | 94% (65/69) | 14% (5/35) | 68% (65/95) | 56% (5/9) |
| HCV RNA day 7 <1000 IU/mL 26% of patients (39/150) | 36% (10/28) | 100% (21/21) | 100% (10/10) | 54% (21/39) | 42% (28/67) | 97% (33/34) | 97% (28/29) | 46% (33/72) |
| HCV RNA undetectable week 4 (RVR) 62% of patients (98/158) | 76% (22/29) | 43% (9/21) | 65% (22/34) | 56% (9/16) | 72% (52/72) | 67% (24/36) | 81% (52/64) | 55% (24/44) |
| Age <40 years or HCV RNA day 7 <1000 IU/mL 52% of patients (82/158) | 57% (16/28) | 95% (20/21) | 94% (16/17) | 62% (20/32) | 78% (56/73) | 75% (27/36) | 86% (56/65) | 61% (27/44) |
| Age <40 years and RVR 27% of patients (43/161) | 24% (7/29) | 95% (20/21) | 88% (7/8) | 48% (20/42) | 45% (33/73) | 95% (36/38) | 94% (33/35) | 47% (36/76) |
| Age ≥40 years and HCV RNA day 7 <1000 IU/mL 10% of patients (16/158) | 25% (7/28) | 100% (21/21) | 100% (7/7) | 50% (21/42) | 12% (9/73) | 100% (36/36) | 100% (9/9) | 36% (36/100) |
| Age <40 years or ITPase Activity <100% or HCV RNA day 7 <1000 IU/mL 65% of patients (102/156) | 79% (22/28) | 85% (17/20) | 88% (22/25) | 74% (17/23) | 83% (60/72) | 53% (19/36) | 78% (60/77) | 61% (19/31) |

have approved the reporting of real-life data from routine clinical patients.

Results

The impact of baseline variables such as age, ITPase activity, liver fibrosis, steatosis, *IL28B* genotype and baseline IP-10, and on-treatment HCV RNA levels day 7 and week 4, as well as combination thereof on outcome following 12 weeks of combination therapy in the NORDynamic trial were re-evaluated separately for HCV genotypes 2 and 3 (PP analysis in Table I). The highest positive predictive values were noted for HCV RNA <1000 IU/mL day 7, which was achieved by 26% of enrolled patients (Figure 1), closely followed by age below 40 years (Figure 2), and approximately half of all patients fulfilled either of these criteria. More than 80% of both genotype 2 and 3 infected patients fulfilling these criteria, subsequently achieved SVR both in intention-to-treat and PP analyses. If ITPase activity <100% also was included, 65% of patients fulfilled any of these criteria, however, the SVR rate among adherent,

HCV genotype 3 infected patients was below 80% (Table I).

Since 2007, duration of pegIFN- α and ribavirin therapy for HCV genotype 2/3 infection mainly has been determined by age in Finland, with patients younger than 40 years being treated for 12 weeks in contrast to patients above 40 years, who received 24 weeks of treatment (Table II). Interestingly, Finnish patients infected with HCV genotype 2 were more likely to be above 40 years of age as compared to genotype 3 (59% age >40 years for genotype 2 vs. 38% for genotype 3, respectively; $p < 0.0001$, Chi-squared), similar to what has previously been reported among the patients enrolled in the NORDynamic study (mean age 47.2 vs. 39.8 years for genotypes 2 and 3, respectively, $p < 0.0001$ Mann-Whitney U -test) [10]. Also a significantly higher proportion of patients below 40 years of age achieved SVR than older patients in spite of being prescribed only half the treatment duration (81% vs. 73% for patients <40 vs. ≥40 years of age respectively; $p = 0.039$, Chi-squared). A non-significant trend was also noted towards greater likelihood of achieving SVR among patients infected

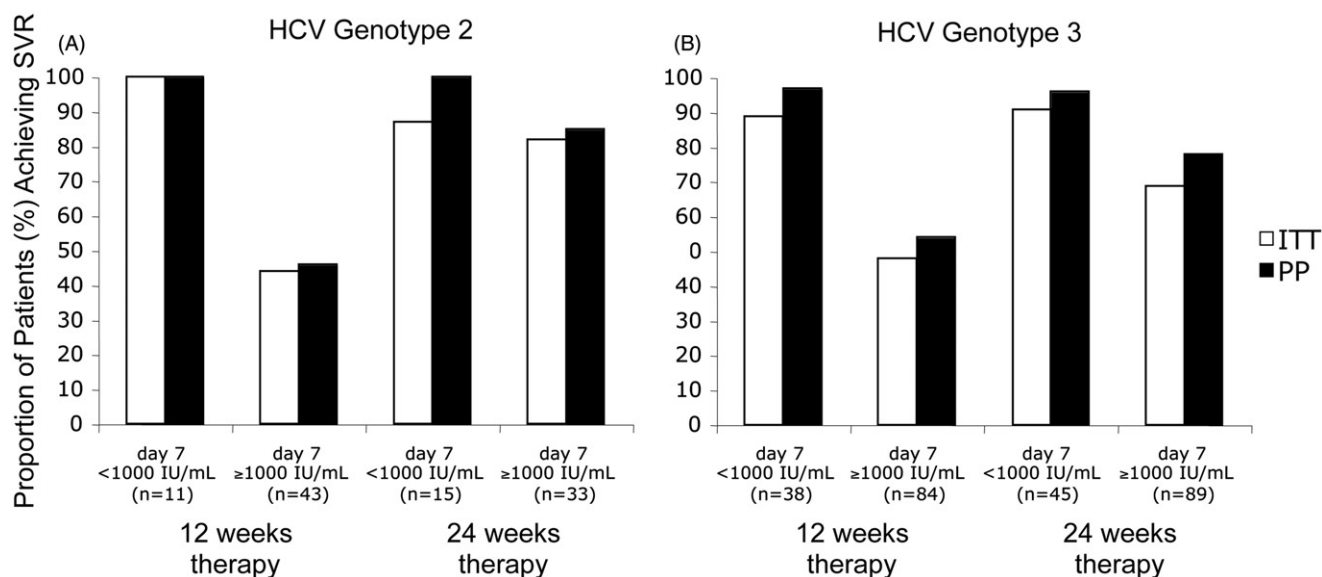


Figure 1. Proportion of HCV genotype 2 (A) or 3 (B) infected patients achieving SVR following 12 or 24 weeks included in the intention-to-treat (ITT) and per-protocol (PP) analyses among patients achieving <1000 vs. \geq 1000 IU/mL day 7 in the NORDynamIC trial. The number of patients under each column reflects the ITT population.

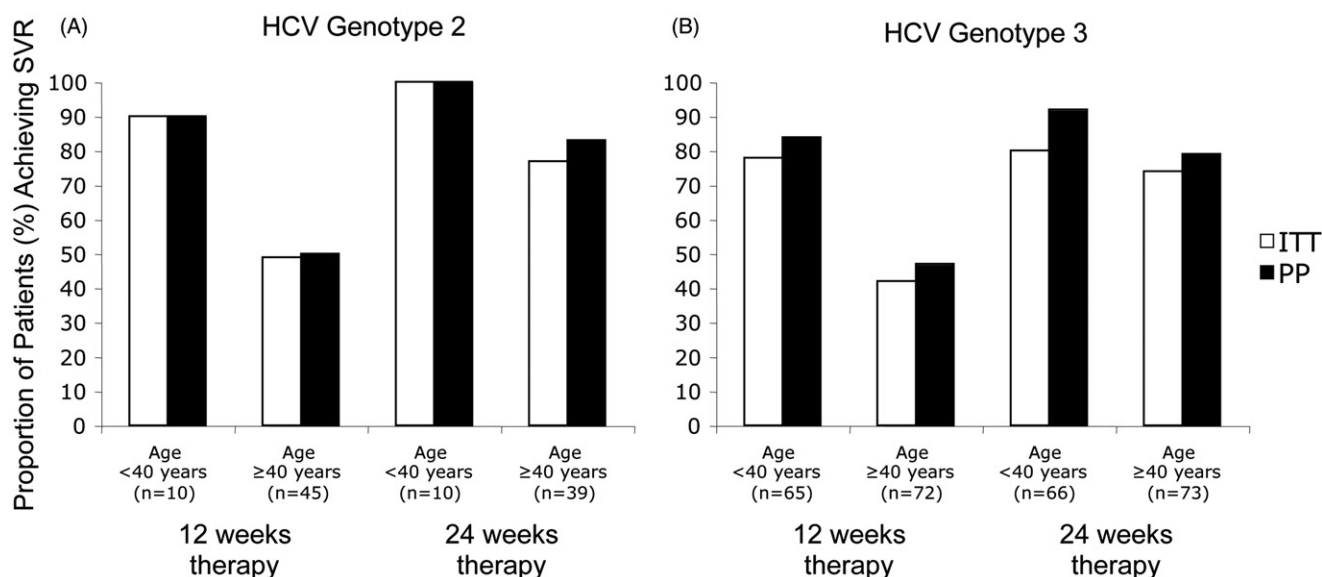


Figure 2. Proportion of HCV genotype 2 (A) or 3 (B) infected patients achieving SVR following 12 or 24 weeks included in the intention-to-treat (ITT) and per-protocol (PP) analyses among patients with age <40 vs. \geq 40 years in the NORDynamIC trial. The number of patients under each column reflects the ITT population.

with HCV genotype 2 vs. 3 (83% vs. 75% for genotypes 2 and 3, respectively). It should be noted that Finnish HCV genotype 2/3 infected patients generally received 800 mg daily flat dosing of ribavirin.

In Sweden, seven centers reported that they routinely offered HCV genotype 2/3 infected patients younger than 40 years of age and/or those achieving <1000 IU/mL day 7 pegIFN- α and ribavirin combination therapy for 12–16 weeks. Among HCV genotype 2 infected

patients, 97% achieved SVR, and among genotype 3 infected, 94% achieved SVR (Table III).

Discussion

The results of this study of both experimental clinical trial and confirming real-life data suggest that combinations of both baseline patient characteristics and/or on-treatment responses can select for suitable HCV genotype 2 or

Table II. Real-Life SVR data among Finish HCV genotype 2/3 infected patients where duration is determined by age; Ribavirin 800 mg per day.

| Year | Genotype 2 | | Genotype 3 | |
|--------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| | <40 years (12 weeks of treatment) | ≥40 years (24 weeks of treatment) | <40 years (12 weeks of treatment) | ≥40 years (24 weeks of treatment) |
| 2007 | 9 of 9 (100%) | 8 of 9 (89%) | 21 of 28 (75%) | 12 of 19 (63%) |
| 2008 | 9 of 11 (82%) | 2 of 4 (50%) | 30 of 37 (81%) | 16 of 21 (76%) |
| 2009 | 8 of 10 (80%) | 11 of 13 (85%) | 24 of 32 (75%) | 16 of 25 (64%) |
| 2010 | 2 of 2 (100%) | 9 of 14 (64%) | 27 of 31 (87%) | 12 of 15 (80%) |
| 2011 | 1 of 1 (100%) | 7 of 7 (100%) | 32 of 35 (91%) | 10 of 12 (83%) |
| 2012 | 5 of 6 (83%) | 9 of 9 (100%) | 14 of 19 (74%) | 13 of 16 (81%) |
| 2013 | 7 of 8 (88%) | 8 of 12 (67%) | 17 of 26 (65%) | 7 of 17 (41%) |
| Total | 41 of 47 (87%) | 54 of 68 (79%) | 165 of 208 (79%) | 86 of 125 (69%) |

Table III. Real-life SVR data among Swedish genotype 2/3 infected patients achieving <1000 IU/mL day 7 or age <40 years treated for 12–16 weeks.

| Center | HCV genotype 2 | HCV genotype 3 | Ribavirin dosing | Treatment duration | Criteria for patient selection |
|--------------|-----------------------|-----------------------|------------------|--------------------|--------------------------------|
| Gothenburg | 6 of 6 | 16 of 17 | 11 mg/kg per day | 12 weeks | <1000 IU/mL day 7 or <40 years |
| Karlstad | 5 of 5 | 5 of 6 | 11 mg/kg per day | 12 weeks | <1000 IU/mL day 7 |
| Gävle | 6 of 6 | 19 of 19 | 11 mg/kg per day | 12–16 weeks | <1000 IU/mL day 7 |
| Borås | 7 of 8 | 9 of 10 | 11 mg/kg per day | 12–16 weeks | <1000 IU/mL day 7 |
| Skövde | 2 of 2 | 18 of 20 | 11 mg/kg per day | 12–16 weeks | <1000 IU/mL day 7 or <40 years |
| Trollhättan | 3 of 3 | 10 of 10 | 11 mg/kg per day | 12–16 weeks | <1000 IU/mL day 7 or <40 years |
| Halmstad | 2 of 2 | 3 of 3 | 800 mg daily | 12–16 weeks | <1000 IU/mL day 7 or <40 years |
| Total | 31 of 32 (97%) | 80 of 85 (94%) | | | |

3 infected candidates with a high likelihood of achieving SVR after as short as 12 weeks of interferon-based combination therapy. From a clinical perspective, baseline factors may be preferential as they do not require initiation of therapy. To this end, age below 40 years is an attractive selective characteristic as it does not require laboratory analyses, and allows for the discussion of short course interferon-based therapy at an early time-point after referral to a tertiary treatment center. HCV RNA below 1000 IU/mL was the best predictor of subsequently achieving SVR, especially among adherent patients, but obviously requires initiation of therapy.

Although the number of Swedish patients offered short-duration treatment thus far has been substantially lower than in Finland, slightly higher SVR rates have been achieved. This possibly could be due to more frequent use of higher, weight-based ribavirin dosing (11 mg/kg weight per day), occasional prolongation of treatment duration to 16 weeks, or more restrictive selection of candidates deemed suitable, e.g. the provision that no dose reductions are performed and RVR is achieved. Additionally, the Finnish patient population included those with advanced liver fibrosis, which also may have contributed to the lower SVR rates achieved. However, it is important to bear in mind that the general use of higher, weight-based ribavirin dosing as compared to 800 mg daily dosing will entail more side effects, primarily anemia.

The side effects of interferon-based combination therapy are substantially more common and severe

than those associated with interferon-free DAA regimens, and must be discussed with patients prior to initiation of therapy as they may negatively impact both on work and social life. Many side effects, however, debut after 12 weeks of therapy, and thus can be avoided by shorter duration. Unfortunately, neuropsychiatric symptoms such as depression often appear as early as after two weeks [24]. The impact of these side effects, however, can be ameliorated by routine monitoring using standardized questionnaires, and early intervention [24]. The management of these side effects demands additional laboratory monitoring and resources of health-care providers, as well as other incremental costs, e.g. sick leave. These issues impact on the cost-effectiveness of interferon-based as compared to DAA-based therapy. However, because of the substantial costs of DAA-based regimens, these treatment options often are reserved for cirrhotic and pre-cirrhotic patients. Thus, patients with mild fibrosis currently are unlikely to be candidates for DAA-based therapy, and in this light, 12 weeks of interferon-based treatment may be attractive for some easy-to-cure HCV genotype 2/3 infected patients with favorable characteristics despite potential side effects.

In conclusion, the results of this study suggest that as short as 12 weeks of interferon and ribavirin therapy is an acceptable alternative for selected HCV genotype 2/3 infected patients, given that a thorough discussion of the potential side effects is provided prior to initiation.

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Declaration of interest

None of the authors have an association that might pose a conflict of interest.

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