Hepatitis C in healthcare personnel: secondary data analysis of therapies with direct-acting antiviral agents

Claudia Westermann 1*, Dana Wendeler 2 and Albert Nienhaus 1, 2

Abstract

Background: Hepatitis C Virus (HCV) infections are blood-borne, generally chronic and are associated with increased morbidity and mortality. The aim of this study is to describe the results of therapies with direct-acting antiviral agents (DAAs) in healthcare personnel.

Methods: Secondary data analysis using data from the Statutory Accident Insurance of the Health and Welfare Service. The study surveyed DAA therapies administered to insured parties (healthcare personnel with an HCV infection recognised as an occupational disease) in Germany between 01/01/2014 and 30/11/2016. The end points were results of monitorings carried out twelve weeks after the end of treatment (SVR12), side effects and the results of the assessment of reduced work ability after treatment. Multivariate logistic regression models were constructed to model SVR12.

Results: The study population (n = 180) comprised 74% women, 90% of the participants had an HCV genotype 1 infection. Two-thirds had fibrosis or cirrhosis and were treatment experienced. The most common combined therapy was ledipasvir and sofosbuvir (49%). A DAA therapy with ribavirin was administered in 20% of cases, with (pegylated) interferon and ribavirin used in 2% of cases. The majority of therapies were completed without any side effects. The overall SVR12 rate was 94%. Significant independent predictor of decrease odds of SVR12 was liver cirrhosis. Positive effects on the healthcare personnel’s work ability were observed after successful therapy.

Conclusion: High SVR12 rates were achieved in the sample population, with positive effects on their work ability. Early HCV therapy seems reasonable due to the increased chance of successful treatment of the infection.

Keywords: Hepatitis C virus, Occupational exposure, Blood-borne infections, Healthcare personnel, Direct-acting antiviral agents

Background

The hepatitis C virus (HCV) is one of the most common infectious diseases in the world and develops into a chronic infection in up to 85% of cases. According to data from the World Health Organisation (WHO), approx. 71 million people globally have a chronic hepatitis C (CHC) infection [1, 2]. CHC is associated with higher morbidity and higher mortality [2, 3]. The use of direct-acting antiviral agents (DAAs) is currently leading to a major shift in the management of chronic HCV infections. DAAs open up the possibility for efficient oral therapy regimens with fewer side effects for patients with or without treatment experience. As recent studies have shown, interferon-free DAA treatments have achieved substantial sustained virological response rates (SVRs) of over 90% [4, 5]. For CHC infections, treatment success is achieved when the HCV virus’s RNA can no longer be detected in the blood (SVR), generally twelve weeks after the end of treatment [6, 7]. SVRs are associated with lowering morbidity and mortality caused by CHC [8, 9].
Healthcare personnel (HP) have contact with infected patients as part of their work. Injuries caused by sharp or pointed objects are some of the most commonly reported workplace accidents [10]. In Germany, reports detailing a reasonable suspicion of occupational illness are submitted to the statutory accident insurance carriers. Despite being on the decrease, Hepatitis C is still one of the most common infections leading to the recognition of an occupational illness among German HP. It is also the most common reason for newly approved retirement on the grounds of occupational disease [11]. Data analysis of an accident insurer shows that despite the number of cases has declined, the costs of HCV infection as an occupational disease (OD) have been significantly increasing over the past 15 years. These costs are the result of the increase in compensation payments for retirement on the grounds of OD and, since 2012, as a result of an increase in the cost of the drugs used to treat the infection [12]. The high costs of DAA therapies are offset by the potentially considerable benefits. The aim of this study is to investigate the treatment results of the DAA therapies in HP.

Methods
Analysis of the DAA therapies using data from the Statutory Accident Insurance of the Health and Welfare Service (Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege, BGW). This analysis was carried out in line with the Consensus German Reporting Standard for Secondary Data Analyses (STROSA) [13]. When applying for DAA therapy for a HP with an occupational CHC infection, the BGW collects data (using a standardised input mask (Excel table)) about the course of treatment for the purposes of conducting an analysis. For quality assurance purposes, this process was discussed and aided by the BGW’s Occupational Diseases working group. Following data was anonymised extracted from doctors’ letters and test results in the insured party’s medical files: genotype, reduced work ability (RWA) grading, treatments used, treatment status (naive/experienced), cirrhosis (yes/no), start and end of treatment (duration), treatment result (RNA evidence), side effects, and assessment of the RWA after DAA therapy. The analysis included data from insured individuals who completed DAA therapy between 01/01/2014 and 30/11/2016 and for whom treatment results were available twelve weeks after the end of therapy. In cases of treatment failure directly following the end of therapy, if there was no data available at twelve weeks after the end of treatment, it was also assumed that treatment had failed. Evidence of virus RNA twelve weeks after the end of treatment following previous ETR (end-of-treatment sustained virological response) was considered a relapse. The end points investigated were treatment success twelve weeks after the end of treatment (SVR12), side effects and the results of assessment of the RWA after the conclusion of DAA therapy.

Determination of RWA in occupational disease procedures
Statutory accident insurance is one of the pillars of German social insurance. On the basis of the 7th German Social Security Code (Siebtes Buch, Sozialgesetzbuch, SGB VII), every employer is legally obliged to insure employees against accidents at work. The sponsorship of statutory accident insurance, the group of insured persons and the procedure in the event of a claim as well as the benefits in the event of an insured event are regulated in this code of law. The essential benefit for insured persons who get injured at the workplace following an accident or who suffer an occupational disease is the entitlement to compensation if their performance and thus their ability to work cannot be fully restored. This entitlement for the injured person’s pension is dependent on the assessment of the RWA and the extent to which the reduction in the physical and mental capacity of an insured person restricts their work opportunities. In the event of a complete loss of working ability (100%), a full pension is paid, which amounts to two thirds of the annual earnings before the occupational disease. In the case of a partial RWA, a partial pension corresponding to the degree of RWA is paid. The entitlement starts with a RWA of at least 20%. For claimants suffering HCV, the RWA is determined by the fibrosis stage and the degree of inflammatory activity of the disease. The initial assessment requires a detailed anamnesis, the clinical status and an abdominal sonography as well as a sufficient laboratory program with clinical-chemical, virological and immunoserological parameters. A reliable differential diagnostic and functional assessment of the liver situation needs to be ensured. Further assessment criteria are the probable duration and the course of the disease and the associated statement on the prognosis. A RWA of 20% should be granted when the CHC infection is accompanied with an increased concentration of the liver enzymes but not with a fibrosis of the liver, whereas a RWA of 50 to 100% should be granted when a cirrhosis is present. However, the grading is performed individually and personal circumstances like fatigue or depression should also be considered. The grading is performed by the case manager of the insurance with the support of a physician. The RWA determines the amount of the pension to be paid, even over the period of working life.

Statistical analysis
Univariate comparisons were made to describe the correlations between treatment success (SVR12) and the categorical variables treatment status (naive/experienced),

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cirrhosis (yes/no), RWA (≤50%/> 50%) and gender. The significance of the correlations was tested using the Fisher’s exact test. Pearson’s correlation coefficient was calculated to measure the statistical association between age and RWA. Multivariate logistic regression models were constructed to model SVR12. Models included cirrhosis, prior treatment, gender, and age (as a continuous variable). Nagelkerke’s R-squared was calculated and used to derive Cohen’s effect size [14]. Using the measure according to Cohen, an f-value of 0.10 equates to a small effect, an f-value of 0.25 to a medium effect and an f-value of 0.40 to a large effect. For all comparisons, a p-Value < 0.05 was considered statistically significant. Data analysis was done using IBM SPSS Statistics version 23.

Results
During the analysis period, a DAA therapy was administered to 180 HP and the SVR was determined twelve weeks after the end of treatment.

Description of the sample (Table 1)
The mean age of the insured individuals was 62 years. For the period under analysis, 60% were under the statutory retirement age of 65 years. The sample population comprised 74% women. The most common type of infection among the sample was HCV genotype 1 (91%), with individual cases caused by viruses of genotypes 2, 3 or 4. No co-morbidities with Hepatitis B or HIV infections were documented. There were histological indications in 76% of the participants (fibrosis 43%; compensated or decompensated cirrhosis 24 and 9%, respectively) before the DAA therapy started and 72% had already experienced a prior treatment. More than 90% of the insured individuals had a RWA, approximately a third had a RWA of more than 50%.

DAA-regimens and side effects (Table 2)
The most common treatment was a combination therapy of ledipasvir (LDV) and sofosbuvir (SOF) (n = 88/49%). A DAA therapy with ribavirin (RBV) was administered in 36 cases (20%), and (pegylated) interferon (PEG-IFN) and RBV were used in four cases (2%). Treatment duration was between eight and 24 weeks, with the majority lasting twelve weeks (71%). For 67% of insured individuals, the treatment was not associated with any side effects. The most common side effect was a combination of mild symptoms such as headaches, nausea and sleep disorders and/or fatigue (26%). 4% of the sample population suffered from skin reactions (pruritus to generalised skin rash, phototoxic reactions), and there were individual cases of decrease in haemoglobin, feelings of anxiety or depression and isolated gastrointestinal disorders. Side effects not linked to the DAA therapy, but seen as symptoms of an advanced CHC infection were summarised as other side effects (bleeding of the oesophageal varices, incipient hepatorenal syndrome). The observed side effects of a decrease in haemoglobin (n = 2) occurred in DAA therapy (LDV/SOF) combined with RBV in prior treated patients with liver cirrhosis. These therapies were conducted for twelve or 24 weeks and led to SVR12 in the insured individuals. Anxiety and depression were observed in

| Table 1 Baseline characteristics (n = 180) |
|------------------------------------------|
| Characteristic (valid values n/%)         |
| Gender                                   |
| Women                                    |
| 133                                      |
| 74                                       |
| Men                                      |
| 47                                       |
| 26                                       |
| Age                                      |
| Mean (SD)                                |
| 62 (10)                                  |
| Median/Minimum/Maximum                   |
| 62/21/88                                 |
| Age group                                |
| 30–39                                    |
| 4                                        |
| 2                                        |
| 40–49                                    |
| 12                                       |
| 7                                        |
| 50–59                                    |
| 50                                       |
| 28                                       |
| 60–64                                    |
| 42                                       |
| 23                                       |
| ≥ 65a                                    |
| 72                                       |
| 40                                       |
| Genotype (11/6)                          |
| 1 sub-type not recognised                |
| 15                                       |
| 9                                        |
| 1a                                       |
| 50                                       |
| 29                                       |
| 1b                                       |
| 88                                       |
| 52                                       |
| 2                                        |
| 6                                        |
| 4                                        |
| 3                                        |
| 7                                        |
| 4                                        |
| 3a                                       |
| 2                                        |
| 1                                        |
| 4                                        |
| 1                                        |
| 1 < 1                                    |
| RWA % (S/3)                              |
| 0 < 20                                   |
| 12                                       |
| 7                                        |
| 20                                       |
| 59                                       |
| 34                                       |
| 30–40                                    |
| 46                                       |
| 26                                       |
| 50–60                                    |
| 35                                       |
| 20                                       |
| 70–80                                    |
| 11                                       |
| 6                                        |
| 90–100                                   |
| 12                                       |
| 7                                        |
| Stage of liver disease (28/16)           |
| No findings                              |
| 37                                       |
| 24                                       |
| Fibrosis                                 |
| 65                                       |
| 43                                       |
| Compensated cirrhosis                    |
| 37                                       |
| 24                                       |
| Decompensated cirrhosis                  |
| 13                                       |
| 9                                        |
| Therapy status (21/12)                   |
| Naive                                    |
| 45                                       |
| 28                                       |
| Experienced                              |
| 114                                      |
| 72                                       |

*statutory retirement age; RWA reduced work ability, SD standard deviation
patients with treatment experience and without liver cirrhosis \((n = 2)\) receiving DAA therapies in combination with ribavirin or PEG-IFN \((\text{SOF}/\text{RBV}/\text{PEG-IFN}; \text{dasabuvir (DSV)/ombitasvir (OBV)/paritaprevir (PTV)/ritonavir (RTV)/RBV})\). These were completed after the standard twelve weeks and led to SVR12 in the insured individuals.

### Treatment results and summary statistics

The ETR rate was 97% and the SVR12 rate was 94% (Table 2). Virus RNA could still be detected in six individuals directly after the end of treatment. At the results monitoring twelve weeks after the end of treatment, six patients showed no change or a reduction in viral load, while four patients had a relapse (Additional file 1: Table S1). The results of univariate and logistic regression analysis regarding treatment response (SVR12) are described in Table 3. Prior experience of treatment resulted in no significant difference in terms of SVR12 (naive \(n = 45/experienced n = 114\): SVR12 98% vs 94%, \(p = 0.44\)), while there was a statistically significant difference with regard to cirrhosis status. For individuals without cirrhosis \((n = 102)\), the treatment was statistically significant more likely to be successful than for patients with diagnosed cirrhosis \((n = 50)\) (SVR12 98% vs 86%, \(p = 0.006\)). For insured individuals with a RWA grading of \(\leq 50\% \,(n = 139)\), the DAA treatment was also statistically significant more likely to be successful than for patients with a higher RWA grading \((n = 36)\) (SVR12 97% vs 86%, \(p = 0.019\)). It was somewhat more likely for women \((n = 133)\) to reach SVR12 after therapy than men \((n = 47)\) (SVR12 96% vs 89%, \(p = 0.130\)). The multivariate regression showed that cirrhosis was a statistically significant independent predictor of decrease odds of SVR12. Participants with cirrhosis were 10 percentage points less likely to reach SVR12 in comparison to patients without cirrhosis. This resulted in an adjusted \(OR = 0.098 \,(95\% \,CI 0.01–0.75; \,p = 0.03)\). With an increase in age, there was also an increase in the probability of achieving SVR12 \((OR = 1.11; \,95\% \,CI 1.01–1.23, \,p = 0.04)\). The variables of prior treatment \((OR = 0.42; \,95\% \,CI 0.05–3.92; \,p = 0.42)\) and gender \((OR = 0.41; \,95\% \,CI 0.08–2.18; \,p = 0.3)\) showed no statistically significant correlation with the end-point SVR12 in the multivariate analysis. Nagelkerke’s R-squared was 0.24, which corresponds to an f-value of 0.56, which Cohen classifies as a large effect size. The liver enzyme laboratory values (GOT, GPT, γGT) for 102 insured individuals at twelve weeks after the end of treatment were available at the time of the evaluation. For 90 (88%) of the individuals, the liver enzymes were in the normal range twelve weeks after the DAA therapy.

### Evaluation of RWA after DAA therapy

Evaluation of RWA after DAA therapy was done for 115 (64%) of the insured individuals, on average nine months after the end of treatment. The RWA was adjusted for 87 (76%) of the insured individuals. The RWA determined before treatment lapsed for 56 individuals, 25 individuals had a decrease in the RWA after the evaluation and six increased their RWA (Table 4). Reasons for an increased RWA included liver transplant after successful DAA therapy, bleeding of the oesophageal varices and incipient hepatorenal syndrome. The correlation between age and RWA was low \((r = 0.16, \,p = 0.04)\).

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**Table 2** DAA treatment regimens and results \((n = 180)\)

| Characteristic | Valid values |
|---------------|--------------|
| Therapies total \((2/1)\) | 178 |
| LDV, SOF | 88 49 |
| SOF, DCV | 29 16 |
| LDV, SOF, RBV | 17 10 |
| SOF, SMV | 11 6 |
| DSV, OBV, PTV, RTV, RBV | 11 6 |
| DSV, OBV, PTV, RTV | 9 5 |
| SOF, RBV | 7 4 |
| SOF, RBV, PEG-IFN | 3 2 |
| DCV, SOF, RBV | 1 < 1 |
| SOF, SMV, RBV | 1 < 1 |
| PEG-IFN, TVR, RBV | 1 < 1 |

| Therapy result | \(\text{Directly after therapy (1/< 1)}\) |
|----------------|----------------------------------|
| ETR | 173 97 |
| Remission | 6 3 |
| Twelve weeks after therapy | 180 |
| SVR12 | 170 94 |
| Remission/viral load unchanged | 6 > 2 |
| Relapse | 4 > 3 |

| Side effects \((13/7)\) | 167 |
|----------------|------|
| None | 110 66 |
| Headaches, nausea, sleep disorder | 43 26 |
| Skin reactions | 6 4 |
| Anaemia | 2 > 1 |
| Depression, anxiety | 2 > 1 |
| Gastrointestinal disorders | 2 > 1 |
| Other* | 1 > 1 |

*Manifestation of advanced infection (hepatorenal syndrome \(n = 1\), bleeding of oesophageal varices \(n = 1\)); DAA direct-acting antiviral agents, LDV ledipasvir, SOF sofosbuvir, DCV daclatasvir, RBV ribavirin, RTV ritonavir, SMV simeprevir, DSV dasabuvir, OBV omibitasvir, PTV paritaprevir, PEG-IFN pegylated interferon, TVR telaprevir, ETR end-of-treatment response, SVR12 sustained virologic response twelve weeks after therapy.
Patients with and without experience of treatment who have a CHC infection achieved high SVR12 (94%) rates in the observed sample. Cirrhosis status (OR 0.098; 95% CI 0.01–0.75; \( p = 0.03 \)) and age (OR 1.11; 95% CI 1.01–1.23; \( p = 0.04 \)) had a significant correlation with treatment success. Significant independent predictor of decrease odds of SVR12 was liver cirrhosis. Even though, the correlation between age and SVR12 was statistically significant, advanced age is no barrier to DAA therapy. SVRs are associated with reducing morbidity and mortality resulting from a CHC infection, irrespective of individual cirrhosis status. They are also associated with an improvement in health-related quality of life [8, 9, 15, 16]. In the study population, positive effects on the patients’ RWA were observed on average nine months after successful completion of therapy. An evaluation was carried out in 64% of the insured individuals after DAA therapy, showing an improvement in work ability for more than 70% of those being analysed. Hence we assume that pension payments will decrease as well.

In a study with patients with a genotype 1 HCV infection, Backus et al. [17] investigated predictors of achieving SVR (at least ten weeks after the end of treatment) to determine the efficacy of LDV/SOF ± RBV and OBV/PTV/RTV/DSV ± RBV. The variables included in the multivariate analysis were treatment status (naive/experienced), ethnic background, body mass index (BMI), cirrhosis status (FIB-4 > 3.25), age and gender. SVR rates of 94% were achieved in the patient collective (average age: 61, 96% male, 23% with experience of treatment, 30% with cirrhosis). Cirrhosis status (OR 0.60; 95% CI 0.49–0.72, \( p = 0.001 \)), having an African-American background (OR 0.71; 95% CI 0.59–0.86, \( p = 0.001 \)) and a BMI of \( \geq 30 \) kg/m² (OR 0.73, 95% CI 0.60–0.89, \( p = 0.002 \)) had a significant correlation with achieving SVR. In another study, no significant differences were found between treatment naive patients with and without cirrhosis in terms of SVR12 (97.9% vs 96.2%) [18]. Overall, the authors reported that no relapses were observed in patients once they had achieved SVR12. According to Zeuzem [19], the lack of evidence of HCV

### Table 3 Summary of univariate and logistic regression analysis for variables regarding treatment response SVR12 (n = 180)

| Variable                      | Missing values | n total | % SVR12 rates | OR (95% CI) | \( p \)-value |
|-------------------------------|----------------|---------|---------------|-------------|--------------|
| Cirrhosis (no/yes)            | 28             | 152 (102/50) | 98% versus 86% | 0.12 (0.03–0.62) | < 0.01 |
| Treatment (naive/experienced) | 21             | 159 (45/114) | 97.8% versus 93.9% | 0.35 (0.04–2.90) | NS          |
| RWA (≤50%/> 50%)              | 5              | 175 (139/36) | 97.1% versus 86.1% | 0.18 (0.05–0.72) | < 0.05 |
| Gender (women/men)            | 0              | 180 (133/47) | 96.2% versus 87.5% | 0.32 (0.09–1.19) | NS          |

**Multivariate logistical regression model with SVR12 as end point**

| Variable                      | Missing values | n total | OR (95% CI) | \( p \)-value | \( R^2 \) |
|-------------------------------|----------------|---------|-------------|---------------|----------|
| Cirrhosis (no/yes)            | 34             | 146 (98/48) | 0.098 (0.01–0.75) | < 0.05 | 0.242    |
| Treatment (naive/experienced) | 34             | 146 (42/104) | 0.42 (0.05–3.92) | NS           |          |
| Gender (women/men)            | 34             | 146 (112/34) | 0.41 (0.08–2.18) | NS           |          |
| Agea                         | 34             | 146     | 1.11 (1.01–1.23) | < 0.05 |          |

SVR12 sustained virologic response twelve weeks after therapy, RWA reduced work ability; Dependent variables - the first category is established as a reference; \( ^a \)as a continuous variable; OR (odds ratio) for the primary end point of SVR12; NS non-significant

### Discussion

Patients with and without experience of treatment who have a CHC infection achieved high SVR12 (94%) rates in the observed sample. Cirrhosis status (OR 0.098; 95% CI 0.01–0.75; \( p = 0.03 \)) and age (OR 1.11; 95% CI 1.01–1.23; \( p = 0.04 \)) had a significant correlation with treatment success. Significant independent predictor of decrease odds of SVR12 was liver cirrhosis. Even though, the correlation between age and SVR12 was statistically significant, advanced age is no barrier to DAA therapy. SVRs are associated with reducing morbidity and mortality resulting from a CHC infection, irrespective of individual cirrhosis status. They are also associated with an improvement in health-related quality of life [8, 9, 15, 16]. In the study population, positive effects on the patients’ RWA were observed on average nine months after successful completion of therapy. An evaluation was carried out in 64% of the insured individuals after DAA therapy, showing an improvement in work ability for more than 70% of those being analysed. Hence we assume that pension payments will decrease as well.

### Table 4 Reduced work ability before and after DAA therapy (n = 115)

| RWA as %          | After DAA therapy | Overall |
|-------------------|-------------------|---------|
|                   | 0–20              | 30–40   | 50–60   | 70–80  | 90–100 | n | % |
| Before DAA therapy| 0                 | 6       | 0       | 0      | 0      | 6 | 5.2 |
|                   | 20                | 38      | 7       | 1      | 0      | 46 | 40 |
|                   | 30–40             | 15      | 4       | 7      | 1      | 0  | 27 | 23.5 |
|                   | 50–60             | 2       | 2       | 10     | 6      | 0  | 20 | 17.4 |
|                   | 70–80             | 1       | 0       | 1      | 0      | 4  | 3  | 9  | 7.8 |
|                   | 90–100            | 0       | 0       | 0      | 4      | 3  | 7  | 6.1 |
| Overall           | 62                | 13      | 19      | 7      | 8      | 6  | 115 |
| %                 | 53.9              | 11.3    | 16.5    | 6.1    | 7      | 5.2 | 100| 100 |

RWA reduced work ability, DAA direct-acting antiviral agents
RNA twelve weeks after the end of DAA therapy signifies a permanent eradication of the virus. Relapses after this point are rare and generally take the form of a reinfection [19]. The most common DAA combination therapy administered in the observed sample was LDV/SOF (49%) and, according to Zimmermann et al. [20], was also the most commonly administered among patients with statutory health insurance in Germany (64%) in 2015. The frequency of the combination of DAA treatments with RBV was not quantified in that particular study. The authors stated a decrease in prescriptions of monthly PEG-IFN therapy regimes from around 2700 in January 2014 to around 650 in December 2015. In this study, a DAA therapy with RBV was administered in 36 cases (20%), and the combination with PEG-IFN and RBV was used in four cases (2%). Treatment was generally administered for twelve weeks (67%). Comparable treatment periods were also observed in the German Hepatitis Cohort (GECCO) [20]. The most commonly described side effects in our study, which were mainly described as mild, were nausea, headaches and sleep disorders, and were also listed by Zeuzem [19] for therapies with SOF and simeprevir (SMV). According to the author, photosensitivity reactions have also been observed during treatment using SMV. These were also observed in our study during combination treatment with SMV, without any consequences for the course of treatment. Decreased haemoglobin was observed in two DAA treatments with LDV/SOF in combination with RBV. The occurrence of haemolytic anaemia during treatment with RBV has been documented in the literature. The therapies were administered successfully (SVR12). In addition, side effects such as anxiety and depression were observed in two individuals with DAA treatments in combination with RBV or PEG-IFN (SOF/RBV/PEG-IFN, DSV/OBV/PTV/RTV/RBV). The treatments were successfully completed (SVR12). The occurrence of depression has been described in the literature both for PEG-IFN and RBV, and particularly when administered as a combination therapy [21, 22].

Cost effectiveness models analysed in the review by Nuno Solinis et al. [15] show that interferon-free DAA therapies are more cost effective than previous interferon-based therapies. The models also showed that early treatment is more cost-effective than therapy in later stages of the disease.

Data analyses showed an increase of costs associated with HCV as an OD in the period from 2000 to 2014 [12]. Despite lower OD HCV prevalence, the cost related to occupational exposure have increased in this period. About of € 87.9 million were spend by the statutory accident insurance for HCV as OD (n = 1.121), of which 60% were attributable to pension payments and around 15% to expenses for pharmaceuticals and other medicines. The cost of CHC are largely defined by the rising expenses for pensions due to increase in RWA. However, there was a strong rise in cost of drug therapy in 2012 to 2014 from € 1.7 to € 2.7 million. In 2015, the cost of antiviral drugs for CHC as OD increased to approximately € 11.9 million [23]. As reported by Zimmermann et al. [20], in 2014 about € 664 million were spent on HCV antivirals by the German statutory health insurance (SHI) and approximately € 1.3 billion in 2015. In Germany, more than 70 million persons are insured by the SHI, which represents about 85% of the German population. DAAs initially involve higher expenses, but as an effective treatment they may reduce long term treatment costs. Although the therapy success is convincing, and in Germany anyone with CHC has general access to DAA therapy, prescriptions have been showing a downward trend among patients with statutory health insurance since the end of 2015 [20]. Some possible reasons listed are insecurities regarding the authorisation of treatments and a lack of clarity in the reimbursement system. As a result of the unspecific course of the disease, researchers assume that around 100,000 people in Germany may have an HCV infection and not know about it [24, 25]. According to the WHO, less than 5% of people with chronic hepatitis worldwide (hepatitis B and C) are aware of their status [26]. The lack of compulsory screening strategies for at-risk groups (e.g. HP, intravenous drug users (IVD), men who have sex with men (MSM) and migrants from countries with high prevalence rates) has been criticised internationally [21, 25, 26]. The implementation of screening strategies to identify infected individuals and to interrupt the channels of infection is a major step in the prevention of the disease [24, 25]. There is no vaccine against HCV infection and a successfully treated infection does not offer protection against reinfection [19, 27]. To prevent reinfecions (i.e. from needle-stick injuries) it is advisable to include employees with DAA therapy into regular check-up schemes.

The case figures presented here do not provide a complete picture for occupational HCV infections. The BGW only records notifications of occupational illness from employees of non-government institutions. This evaluation is based on register data with specific socio-demographic information, the data is not clinical in nature and not always complete (e.g. missing’s in stage of liver disease (15.6%) and treatment experience (11.7%)). Information about co-infections with HBV or HIV could not be evaluated from this database in a statistically valid way because it has not been requested in a standardised form. However, we assume that there is a lower likelihood of co-infection with HBV or HIV because the individuals in the study were HP. These employees have
Conclusions

Patients with and without experience of treatment who have a CHC infection achieved high SVR rates in the observed sample. Early treatment is preferable in order to keep the individual disease burden as low as possible. It appears that early treatment is also indicated for cost reasons, e.g. as a result of the influence of cirrhosis on treatment success. DAA therapies make it possible to eradicate the HCV viruses, thus enabling early recovery from the chronic infection. SVRs are associated with substantial reductions in the individual disease burden and with the patient maintaining their ability to work. Over the long term, this will probably lead to cost savings for statutory accident insurers and also for other social security systems. However, we require long-term experiences with DAA therapies in order to be able to reliably interpret the results. Successful completion of treatment does not provide protection from reinfection. HCV screening programmes for at-risk groups are therefore essential, even after successful treatment.

Additional file

**Additional file 1: Table S1. Characteristics according to treatment response without ETR and/or SVR12. (DOCX 14 kb)**

**Abbreviations**

BGW: Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege; CHC: Chronic hepatitis C; DAA: Direct-acting antiviral agent; DSV: Dasabuvir; ETR: End-of-treatment sustained virological response rate; GECCO: German Hepatitis Cohort; HBV: Viral hepatitis B; HCV: Viral hepatitis C; HIV: Human immunodeficiency virus; HP: Healthcare personnel; IVD: Intravenous drug users; LDV: Ledipasvir; MSM: Men who have sex with men; OBV: Ombitasvir; OD: Occupational disease; PEG-IFN: Pegylated interferon; PTV: Paritaprevir; RBV: Ribavirin; RNA: Ribonucleic acid; RTV: Ritonavir; RWA: Reduced work ability; SOF: Sofosbuvir; STROSA: A Consensus German Reporting Standard for Secondary Data Analyses; SVR: Sustained virological response rate; WHO: World Health Organisation

**Acknowledgements**

We would like to thank the Occupational Diseases working group (BGW) for their support.

**Funding**

No special funds were received for this study. However, the Institute for Health Services Research in Dermatology and Nursing of the University Medical Centre Hamburg-Eppendorf (UKE) receives an unrestricted fund from the Institution for Statutory Accident Insurance and Prevention in the Health and Welfare services (BGW) on an annual basis to maintain the working group at the UKE. The funds are provided by a non-profit organization that is part of the social security system in Germany. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Availability of data and materials**

The original data are property of the Institution for Statutory Accident Insurance and Prevention in the Health and Welfare Services (BGW). The aggregated data as they were provided by the insurance are available upon reasonable request by the head of the department Prof. Dr. Albert Nienhaus (anienhaus@uke.de).

**Authors’ contributions**

CW and AN developed the study design. DW and AN conducted the data analysis. The interpretation of the data was made by DW, CW and AN. CW wrote the manuscript, with significant contribution from the other authors. Uncertainties were discussed between the authors regularly. AN revised the manuscript critically for important intellectual content and gave final approval for the version to be published. All authors read and approved the final manuscript and gave approval for publication.

**Ethics approval and consent to participate**

The study was not submitted to an ethic commission as only anonym routine data of an insurance were used and no personal data were collected and no medical test was performed in the scope of the study. In accordance with the Professional Code for Physicians in Hamburg (Art. 15, 1., Status of 10.03.2014) and the Chamber Legislation for Medical Professions in the Federal State of Hamburg (HmbKGH) it is only necessary to obtain advice on questions of professional ethics and professional conduct from an Ethics Committee if data which can be traced to a particular individual is being used in a research project. However, the study was approved by the data protection board of the insurance which provided the data.

**Competing interests**

The authors declare that they have no competing interests.

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Author details
1Competence Centre for Epidemiology and Health Services Research for Healthcare Professionals (CCCare), Institute for Health Services Research in Dermatology and Nursing (IVDP), University Medical Centre Hamburg-Eppendorf (UKE), Martinistr. 52, 20146 Hamburg, Germany.
2Department of Occupational Medicine, Hazardous Substances and Public Health, Institute for Statutory Accident Insurance and Prevention in the Health and Welfare Services (BGW), Pappelallee 33-37, 22089 Hamburg, Germany.

Received: 8 January 2018 Accepted: 8 May 2018

Published online: 25 May 2018

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