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# Impact of an electronic medical record reminder on hepatitis B vaccine initiation and completion rates among insured adults with diabetes mellitus

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ABSTRACT

*Objective:* The Advisory Committee on Immunization Practices recommends Hepatitis B (HepB) vaccine for previously unvaccinated adults <60 years with diabetes mellitus. This observational retrospective cohort study assessed the impact of implementing electronic provider reminders on HepB vaccine initiation and 3-dose series completion rates among insured adults with diabetes aged 19–59 years old.
*Research design and methods:* Difference-in-difference (DID) analyses compared changes in vaccine initiation and completion rates (ratio of the rate ratio [RRR] and 95% confidence interval [CI]) during 12 months pre- and post-implementation between intervention and control sites. We examined trends in vaccine initiation and completion rates by plotting monthly rates during the study period. We also calculated the overall HepB vaccine coverage rates with 95% CI among all adults with diabetes aged 19–59 years old at the start and end date of the study period.
*Results:* Baseline HepB vaccine initiation and completion rates were similar at both the intervention and control sites. Gender, age, and race/ethnicity distributions within both sites were similar during the 12 months pre- and post-implementation. DID analyses demonstrated statistically significant differences in the changes of the annual vaccine initiation rates (RRR: 70.7, 95% CI: 62.8–79.6) and the third dose completion rates (RRR = 18.7, 95% CI: 14.2–24.8) between the two sites. The coverage increased significantly at the intervention site while it remained low at the control site.
*Conclusions:* Use of provider reminders is highly effective in increasing both HepB vaccine initiation and series completion rates among adults with diabetes.


*Abbreviations:* ACIP, Advisory Committee on Immunization Practices; CI, confidence interval; DID, difference-in-difference; EMR, electronic medical record; HepB, hepatitis B; HBV, hepatitis B virus; ICD-9, International Classification of Diseases – Ninth Revision; KP, Kaiser Permanente; KPNC, Kaiser Permanente Northern California; KPSC, Kaiser Permanente Southern California; MCO, managed care organization; NHANES, National Health and Nutrition Examination Surveys; RR, rate ratio; RRR, ratio of rate ratio; US, United States.

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## Focus on patient

**Context –** On October 25, 2011, the Advisory Committee on Immunization Practices (ACIP) recommended that all previously unvaccinated adults aged 19 through 59 years old be vaccinated against Hepatitis B (HepB) upon diagnosis of diabetes. However, adoption of the preventative intervention remains low.

**New –** Electronic medical record (EMR) provider reminders and alert were successfully used to increase HepB vaccination initiation and completion in patients with diabetes.

**Impact –** Vaccination can significantly reduce morbidity and mortality associated with HepB. Adoption of innovative health technologies, such as EMR reminders and alerts may result in significant public health gains.

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## 1. Introduction

Hepatitis B virus (HBV) causes acute and chronic infection of the liver leading to substantial morbidity and mortality. Diabetes mellitus is independently associated with an increased risk for acute hepatitis B (HepB) among adults without HBV risk behaviors. A previous study reported persons aged 23 through 59 years old with diabetes had 2.1 (95% confidence interval [CI]: 1.6–2.8) times the odds of developing acute HepB as those without diabetes; the odds were 1.5 (95% CI: 0.9–2.5) times as likely for persons aged ≥60 years [1]. Many studies have shown that diabetes is associated with the progression of severe liver outcomes in adults with HBV, including delayed seroclearance, cirrhosis, hepatocellular carcinoma, post-transplant mortality and death [2].

In the United States (US), between 1996 and 2011, the majority (25 out of 29) of the outbreaks of HBV infection in long-term care facilities involved adults with diabetes receiving assisted blood glucose monitoring [3]. In October 2011, the ACIP Work Group recommended HepB vaccination for previously unvaccinated adults as soon as possible after diagnosis of diabetes in two recommendation categories A and B; A includes adults aged 19 through 59 years of age and B includes adults ≥60 years who may be vaccinated at the discretion of their provider following risk assessment and likelihood of adequate immune response [4]. However, the vaccination rate among adults with diabetes was suboptimal. According to national data from the 2013–2014 National Health and Nutrition Examination Surveys (NHANES), HepB vaccination coverage (receipt of ≥3 doses) for persons with diabetes was 33.8% for those aged 19–59 years old [5]. The National Health Interview Survey (NHIS) reported a HepB vaccine coverage of 23.5% for persons aged 19–59 years with diabetes in 2014 [6], while the estimates for overall coverage in all persons with diabetes was 26.3% in 2013, 28.6% in 2012 and 26.9% in 2011 [7–9].

The low national coverage rates of HepB vaccination among adults diagnosed with diabetes in the three years following the ACIP recommendation warranted investigation of the effectiveness of innovative interventions on vaccination rate. It has been shown that electronic medical record (EMR) provider reminders can facilitate improvement in vaccination rate in elderly patients [10]. The Community Preventive Services Task Force recommends implementing provider reminders to increase appropriate vaccination [11]. In this study, we sought to assess the impact of EMR provider reminders on HepB vaccine initiation and series completion rates among insured adults aged 19–59 years old with diabetes in a large, integrated managed care organization (MCO) in the US.

## 2. Research design and methods

### 2.1. Setting

We conducted an observational retrospective cohort study using EMR data from Kaiser Permanente Southern California (KPSC) and Kaiser Permanente Northern California (KPNC). Vaccines are typically provided to KP members at no charge, which is an incentive for members to receive immunizations within the system. Because for outside providers to be reimbursed by the health plan for covered emergency or contract care, claims must be submitted with documentation of the episode of care, the capture of care delivered to members by electronic administrative data was reasonably assumed to be very comprehensive.

### 2.2. Electronic reminders and alerts

The KP EMR system is a customized version of an Epic Systems Corporation electronic health record. Electronic reminders and alerts are widely used in the KP EMR system to assist providers in identifying high-risk patients and addressing care gaps [12]. Electronic reminders are posted to a patient's chart in the EMR under a special tab. Physicians and nurses can click on the tab any time to review care gaps that need attention including immunization and screening tests due. An electronic alert is a "hard-stop" clinical decision support tool, which pops up on the computer screen when a provider opens a patient's chart during a visit. Providers need to act on the alert (such as ordering a test or vaccination) or dismiss it manually. KPSC adopted the October 2011 ACIP recommendation for HepB vaccination among adults with diabetes in January 2012. Following this adoption, since November 2013, KPSC deployed a series of electronic provider reminders and alerts targeting previously unvaccinated adult patients with diabetes aged 19 through 59 years old (Fig. 1). The reminders and alerts were triggered when a dose was due and removed from the patient's chart after the patient received the appropriate dose. During the same study period, there was no EMR provider reminder or alert for HepB vaccination implemented at KPNC.

### 2.3. Study population

Adults with diabetes aged 19–59 years old who were due for each dose of the 3-dose HepB vaccine series from January 1, 2012 (date of ACIP recommendation adoption) through July 31, 2015 were retrospectively identified at KPSC and KPNC. Diagnosis of diabetes was ascertained through International Classification of Diseases – Ninth Revision (ICD-9) diagnosis codes, laboratory test results, and dispensing record of diabetes medications in the last three years in EMR. Specifically, patients were included in the study cohort if they had 2 or more outpatient ICD-9 codes on different days indicating diabetes or gestational diabetes, or if they had at least one ICD-9 code and also met at any of the four conditions in the last three years: 1) any history of hemoglobin A1C > 7.5% or fructosamine >319 μm, or 2) A1Cs ≥ 6.5% at two or more occasions in the past 24 months, or 3) a dispensing record of an oral hypoglycemic or insulin, or 4) any history of more than one fasting blood glucose >126 mg/dL and a dispensing record of one of metformin HCl, exenatide, pioglitazone HCl, rosiglitazone

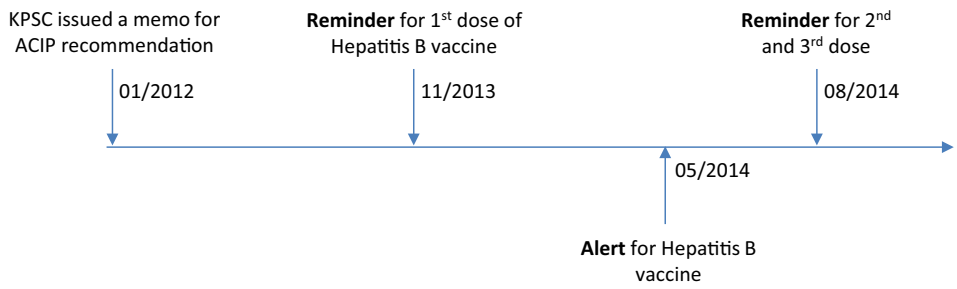


**Fig. 1.** Timeline for Hepatitis B vaccine reminders/alert for adults with diabetes aged 19–59 years old at Kaiser Permanente Southern California (KPSC). The alert introduced in May 2014 was implemented for all three vaccine doses.

maleate, or repaglinide. Subjects were excluded from the analyses if they met any one of the following criteria at entry into the cohort: 1) previous HepB vaccine history (for the first-dose initiation analysis only), 2) positive test result of HepB surface antibody or HepB antigen or HepB viral DNA, 3) documented allergy to the HepB vaccine, 4) female patient with a documented pregnancy within the last 18 months, 5) patient in hospice, under custodial care in a skilled nursing facility, or palliative care, or deceased, 6) post-renal transplant (during the first six months following the renal transplant procedure). Since the US instituted the universal infant HepB vaccination in 1991, we also excluded individuals who were born in or after 1991 from the analyses. These excluded individuals constituted less than 5% of the entire study sample. Adults with diabetes at KPSC who were eligible for HepB vaccination served as the intervention group, and eligible adults with diabetes at KPNC served as the control group.

### 2.4. Statistical analysis

***Descriptive analysis of demographics and healthcare utilization*** We compared the distribution of the subjects' demographics (age, sex, and race/ethnicity) and healthcare utilization (i.e., number of outpatient visits) within KPSC (intervention group) and KPNC (control group) who were eligible for HepB vaccine during the corresponding pre- and post-implementation periods. Frequency and percentage were generated for categorical variables; mean, standard deviation, and median (where applicable) were provided for continuous variables. Standardized difference was used to assess the difference of the distribution in pre- and post-implementation periods regarding characteristics for KPSC and KPNC groups separately. We calculated standardized difference instead of p-value to examine the significance of the differences, because p-value is sensitive to the sample size (i.e., a large sample size would result in a significant p-value with a very small difference). An absolute standardized difference less than 0.1 suggests that the difference in the distribution of the covariates was negligible. We conducted separate descriptive analyses for the initiation of the first dose and the completion of the HepB vaccine series.

***HepB vaccine initiation and series completion rates*** We calculated the annual HepB vaccine initiation rates (with 95% CI) among eligible adults during a 12 month pre- (11/2012–10/2013) and post- implementation of the initial reminder (11/2013–10/2014) in both study groups. Similarly, the annual HepB vaccine series completion rates (with 95% CI) among eligible diabetic adults were calculated for both groups during a 12 month pre- (05/2013–04/2014) and post-implementation of the alert (05/2014–04/2015). The monthly vaccine initiation and completion rates during 01/2012–07/2015 were calculated based on person-time and plotted to present the secular trend during the study period across pre- and post-implementation. The completion rate was calculated among those who had received the second dose and were due for the third dose. As the reminders and alert would be unlikely to influence patients who did not have a healthcare encounter, we conducted a post-hoc sensitivity analysis limiting the study sample to those who had at least one outpatient visit during the study period.

***Difference-in-difference (DID) analysis*** We performed two separate DID analyses to compare the difference in the change in HepB vaccine initiation and completion rates (ratio of rate ratio, RRR; 95% CI), between the eligible adults with diabetes in intervention and control groups during the same 12-month pre- and post-implementation of the electronic provider reminders and the alert, respectively. The DID method adjusts for time-stable confounders within each group and time-varying confounding of a similar pattern and magnitude across both intervention and control groups [13]. Assuming the distribution of confounding remained similar among the patients within the two groups over the time periods across pre- and post-implementation of the reminders, the observed difference in the changes in HepB vaccine initiation and series completion rates between the two groups can be attributed to the effect of the reminders and alert. We also performed stratified DID analysis by age, sex, race/ethnicity and healthcare utilization to explore potential effect modifier covariates.

***Vaccine coverage at the start and end of follow-up*** After excluding persons born after 1991, we calculated overall HepB vaccine coverage rates with 95% CI among all adults aged 22–59 years old diagnosed with diabetes at the start and end date of the study period (01/01/2012 and 07/31/2015). The proportion of the individuals who ever received one dose or completed three doses of HepB vaccine series were calculated and compared between the intervention and control groups.

We performed statistical analyses using SAS, version 9.3 (SAS Institute, Cary, NC).

## 3. Results

At KPSC, we identified 116,217 adults with diabetes (55% males) during the 12-months pre-implementation period and 117,305 adults (55% males) during the 12-months post-implementation period who were eligible for the first dose of HepB vaccination. We identified 85,381 eligible adults (56% males) and 89,563 adults (56% males) respectively during the same periods of time at KPNC. The distributions of gender, age, and race/ethnicity within each study site were similar during the 12 months pre- and post-implementation periods (Table 1). There were 2391 individuals (51% males) during the 12-months pre-implementation period and 15,724 individuals (51% males) during the 12-months post-implementation period who were eligible for the third dose of HepB vaccine at KPSC. The number of eligible individuals for the third dose was similar during the study period at KPNC, with 2327 individuals (52% males) during the 12-months pre-implementation period and 2576 individuals (51% males) during the 12- months post-implementation period (Table 1).

The first-dose vaccine initiation rate among previously unvaccinated adults with diabetes increased from 1.01 to 70.42 per 100 person-years at KPSC in 12 months following the implementation of the initial reminder (rate ratio, RR = 69.5, 95% CI: 65.3–74.1), and the increase was observed across all gender, age, and race/ethnicity groups. There was no significant change in the HepB vaccine uptake at KPNC during the same period (1.06 vs. 1.04 per 100 person-years; RR = 1.0, 95% CI: 0.9–1.1). During the 12 months following the implementation of the EMR alert in May 2014, the third dose completion rate among those who had received the first two doses increased from 8.93 to 177.23 per 100 person-years at KPSC (RR = 19.9, 95% CI: 17.0–23.1), while there was no significant change observed at KPNC during the same period (7.05 vs. 7.47 per 100 person-years; RR = 1.1, 95% CI; 0.8–1.3). The DID analyses demonstrated that the reminder and alert were significantly attributed to the increase in the HepB vaccine initiation and 3-dose series completion rates, with the 95% CI of the estimated RRRs in the overall study population being greater than 1 (Table 2).

The monthly vaccine initiation and completion rates were similar at both study sites before November 2013 (pre-implementation). HepB vaccine initiation rate substantially increased at KPSC (intervention site) after November 2013 when the first electronic reminder of the HepB vaccine for previously unvaccinated patients with diabetes was implemented (Fig. 2A). The 3rd dose completion rate substantially increased after May 2014 when the alert for all three HepB vaccine doses was implemented (Fig. 2C). The completion rate continued to increase at KPSC after another reminder for subsequent doses was implemented in August 2014. However, after

**Table 1**
Demographic characteristics of adults with diabetes aged 19–59 years at study entry, one year prior vs. one year post implementation of the first hepatitis B vaccination reminder.

| | Kaiser Permanente Southern California (intervention site) | | | | | Kaiser Permanente Northern California (control site) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reminder for the first dose | 1 year prior to implementation (N = 116,217) | | 1 year after implementation (N = 117,305) | | Standardized difference | 1 year prior to implementation (N = 85,381) | | 1 year after implementation (N = 89,563) | | Standardized difference |
| Gender | n | % | n | % | −0.002 | n | % | n | % | 0.0025 |
| Female | 52,349 | 45.04 | 52,958 | 45.15 | | 37,420 | 43.83 | 39,143 | 43.7 | |
| Male | 63,868 | 54.96 | 64,347 | 54.85 | | 47,961 | 56.17 | 50,420 | 56.3 | |
| Age* (years) | | | | | 0.0214 | | | | | 0.005 |
| 22–29 | 2191 | 1.89 | 1948 | 1.66 | | 1231 | 1.44 | 1265 | 1.41 | |
| 30–39 | 12,002 | 10.33 | 11,968 | 10.2 | | 8124 | 9.51 | 8451 | 9.44 | |
| 40–49 | 35,160 | 30.25 | 35,007 | 29.84 | | 25,563 | 29.94 | 26,718 | 29.83 | |
| 50–59 | 66,864 | 57.53 | 68,382 | 58.29 | | 50,463 | 59.1 | 53,129 | 59.32 | |
| Race/Ethnicity | | | | | 0.0117 | | | | | 0.0225 |
| Asian/Pacific Islander | 12,510 | 10.76 | 12,643 | 10.78 | | 17,452 | 20.44 | 18,508 | 20.66 | |
| Hispanic | 57,931 | 49.85 | 58,910 | 50.22 | | 23,664 | 27.72 | 25,363 | 28.32 | |
| Non-Hispanic Black | 12,713 | 10.94 | 12,893 | 10.99 | | 9183 | 10.76 | 9614 | 10.73 | |
| Non-Hispanic White | 28,845 | 24.82 | 28,538 | 24.33 | | 31,383 | 36.76 | 32,029 | 35.76 | |
| Others/unknown | 4218 | 3.63 | 4321 | 3.68 | | 3699 | 4.33 | 4049 | 4.52 | |
| Reminder for the 2nd and 3rd dose | 1 year prior to implementation (N = 2391) | | 1 year after implementation (N = 15,724) | | Standardized difference | 1 year prior to implementation (N = 2327) | | 1 year after implementation (N = 2576) | | Standardized difference |
| Gender | n | % | n | % | 0.0118 | n | % | n | % | −0.0193 |
| Female | 1178 | 49.27 | 7654 | 48.68 | | 1123 | 48.26 | 1268 | 49.22 | |
| Male | 1213 | 50.73 | 8070 | 51.32 | | 1204 | 51.74 | 1308 | 50.78 | |
| Age* (years) | | | | | 0.2819 | | | | | 0.0322 |
| 22–29 | 79 | 3.3 | 166 | 1.06 | | 61 | 2.62 | 64 | 2.48 | |
| 30–39 | 380 | 15.89 | 1452 | 9.23 | | 411 | 17.66 | 432 | 16.77 | |
| 40–49 | 714 | 29.86 | 4481 | 28.5 | | 715 | 30.73 | 780 | 30.28 | |
| 50–59 | 1218 | 50.94 | 9625 | 61.21 | | 1140 | 48.99 | 1300 | 50.47 | |
| Race/Ethnicity | | | | | 0.2397 | | | | | 0.0193 |
| Asian/Pacific Islander | 323 | 13.51 | 1477 | 9.39 | | 599 | 25.74 | 664 | 25.78 | |
| Hispanic | 1087 | 45.46 | 8966 | 57.02 | | 607 | 26.09 | 690 | 26.79 | |
| Non-Hispanic Black | 319 | 13.34 | 1609 | 10.23 | | 294 | 12.63 | 320 | 12.42 | |
| Non-Hispanic White | 600 | 25.09 | 3296 | 20.96 | | 740 | 31.8 | 811 | 31.48 | |
| Others/unknown | 62 | 2.59 | 376 | 2.39 | | 87 | 3.74 | 91 | 3.53 | |

* Age at the first time entering the cohort during the observation period (1 year prior vs. post implementation of the 1st hepatitis B vaccination reminder).

**Table 2**
Estimate of ratio of rate ratio using difference-in-difference analysis, adjusted for age at cohort entry, gender, and race/ethnicity.

| | Ratio of Rate Ratio (RRR) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initiation Rates | | | | Completion Rates | | | |
| | RRR | 95% Wald CI | | p-value | RRR | 95% Wald CI | | p-value |
| Overall | 70.67 | 62.76 | 79.59 | <.0001 | 18.74 | 14.15 | 24.83 | <.0001 |
| Gender | | | | | | | | |
| Female | 72.31 | 60.38 | 86.59 | <.0001 | 25.37 | 16.83 | 38.25 | <.0001 |
| Male | 69.11 | 59.00 | 80.94 | <.0001 | 14.19 | 9.63 | 20.91 | <.0001 |
| Age (years) | | | | | | | | |
| 22–29 | 118.46 | 37.13 | 377.89 | <.0001 | 7.00 | 0.55 | 89.04 | 0.13 |
| 30–39 | 46.59 | 32.85 | 66.06 | <.0001 | 16.89 | 7.91 | 36.06 | <.0001 |
| 40–49 | 70.43 | 56.55 | 87.71 | <.0001 | 19.92 | 12.44 | 31.88 | <.0001 |
| 50–59 | 75.11 | 64.26 | 87.79 | <.0001 | 17.11 | 11.40 | 25.68 | <.0001 |
| Race/Ethnicity | | | | | | | | |
| Asian/Pacific Islander | 56.85 | 44.34 | 72.89 | <.0001 | 9.17 | 5.35 | 15.70 | <.0001 |
| Hispanic | 82.93 | 66.45 | 103.49 | <.0001 | 19.67 | 11.70 | 33.08 | <.0001 |
| Non-Hispanic Black | 51.04 | 35.05 | 74.33 | <.0001 | 37.20 | 13.30 | 104.07 | <.0001 |
| Non-Hispanic White | 63.68 | 50.70 | 79.99 | <.0001 | 19.98 | 11.80 | 33.85 | <.0001 |
| Others/Unknown | 85.92 | 45.43 | 162.49 | <.0001 | 43.61 | 7.23 | 262.87 | <.0001 |
| At least one outpatient visit | 74.01* | 65.67 | 83.42 | <.0001 | 23.20† | 17.47 | 30.81 | <.0001 |

CI, confidence interval; KPNC, Kaiser Permanente Northern California; KPSC, Kaiser Permanente Southern California.

* There were 104,136 (out of 116,217, 89.6%) and 104,897 (out of 117,305, 89.4%) patients with at least one OP visit from KPSC prior to and after implementation, respectively; There were 73,415 (out of 85,381, 86.0%) and 76,189 (out of 89,563, 85.1%) patients with at least one OP visit from KPNC prior to and after implementation, respectively.

† There were 2157 and 11,266 patients with at least one OP visit from KPSC prior to and after implementation, respectively; There were 2206 and 2232 patients with at least one OP visit from KPNC prior to and after implementation, respectively.

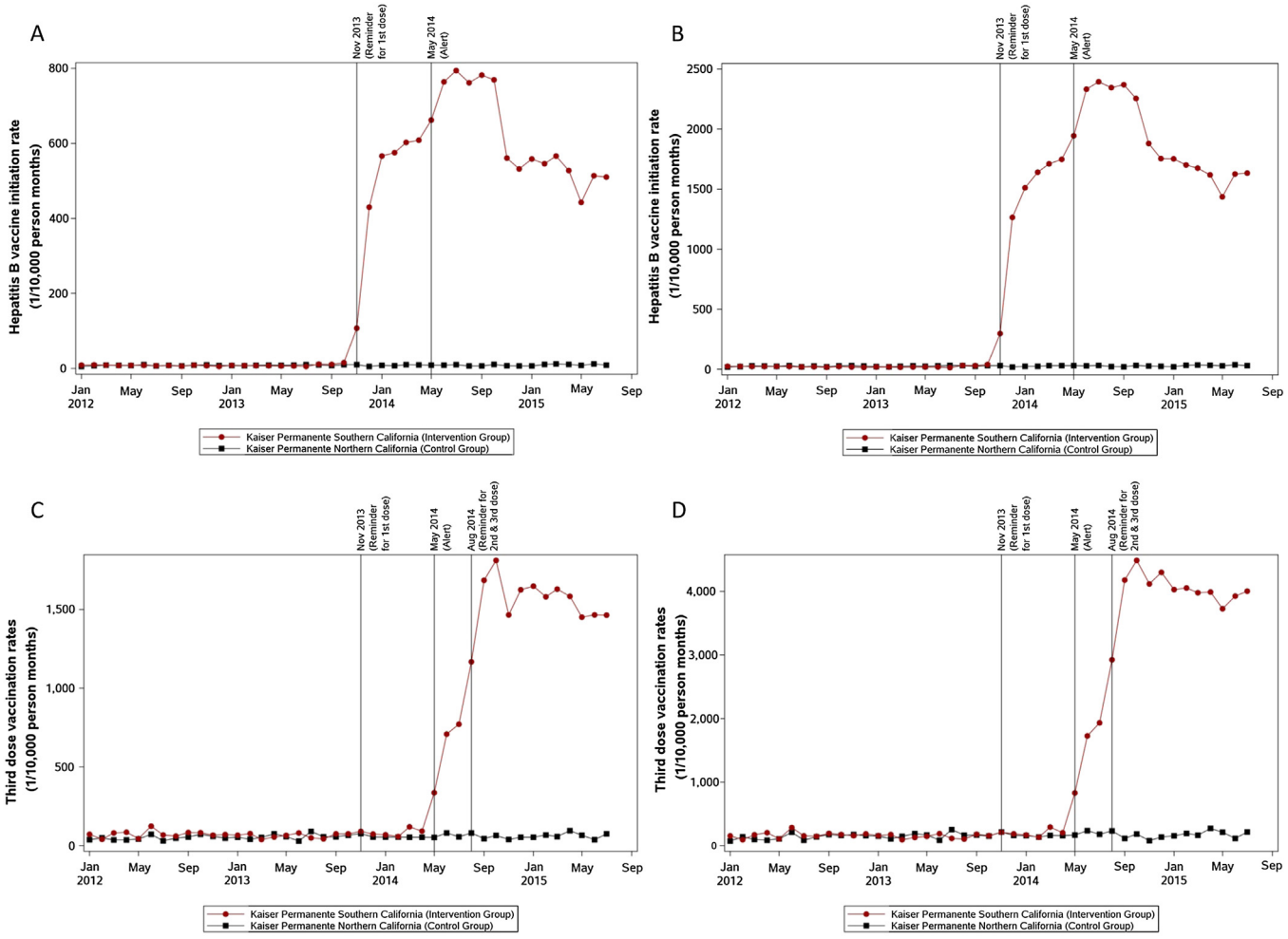


**Fig. 2.** Hepatitis B vaccination initiation and completion rates across intervention and control groups among adults with diabetes mellitus aged 19–59 years old, Jan 2012-July 2015. (A) Initiation rates among the overall study population. (B) Initiation rates among persons with at least one outpatient encounter during the calendar month (sensitivity analysis). (C) Completion rates among the overall study population. (D) Completion rates among persons who had at least one outpatient encounter during the calendar month (sensitivity analysis).

a few months following the last implementation of the alert in May 2014, the vaccine initiation rate decreased and then plateaued. During the same period, the rates of vaccine initiation and completion at KPNC (control site) remained low (Fig. 2A, C).

The majority of patients (over 89% in the intervention site and about 85% in the control site) had at least one outpatient visit during the study period, and the patient healthcare utilization was similar before and after implementation within both sites. In the sensitivity analysis, we observed similar trends after we limited the study sample to those who had at least one outpatient visit during the study period (Fig. 2B, D).

Among all adults aged 19–59 years old with diabetes, the proportion of patients who received at least one dose of HepB vaccine increased from 12.3% on 01/01/2012 to 66.6% on 07/31/2015 across all gender, age groups, and race/ethnicity at KPSC, while this vaccine initiation rate remained low at KPNC (14.5% and 16.8%, respectively). The 3-dose series coverage rate increased from 7.6% on 01/01/2012 to 29.4% 07/31/2015 at KPSC, however, the coverage rate remained low at KPNC (9.4% and 10.8%, respectively).

## 4. Discussion

The findings from this study indicated that use of an EMR provider reminder and alert in an integrated health care setting was highly effective in increasing HepB vaccine initiation and completion rates among previously unvaccinated adults with diabetes. The rapidly increasing trend of the HepB vaccination rates immediately following the implementation of reminders and an alert at the intervention site suggested that these physician decision support tools embedded in an EMR system could have an immediate substantial impact on physician vaccine ordering behavior and patient vaccine uptake. However, after the initial steep increase in vaccine initiation and completion rates following the interventions, the rates levelled off and started to drop, then stayed at a lower level. It is possible that the initial rapid increase in the vaccination rate observed in the intervention group was due to a "catch-up effect", where a large proportion of the eligible patients received the vaccination right after the intervention. However, a proportion of the remaining eligible patients who did not receive the vaccine after the initial months might have been less likely to accept the vaccine regardless of the intervention. There may have been other unmeasured factors influencing vaccination rates. This observed decrease in vaccination rate after a few months following the initial increase suggested that the effect of such intervention may be waning over time and a relatively longer observation period should be used in future studies to evaluate the long-term intervention effect on vaccination rates. Further investigations may identify potential areas for improvement or additional patient-level interventions (such as patient outreach programs) that may boost the long-term effect.

The magnitude of the increase in vaccine initiation was substantial (about 70-fold) and statistically significant at the intervention site. The significant increase in both vaccine initiation and 3-dose regimen completion rates were attributable to the implementation of the targeted EMR reminder and alert, because the baseline vaccine initiation rates were similar at the two study sites and the vaccine initiation and completion rates remained low in the control site (KPNC) during the same study period. In addition, the distributions of the demographic characteristics were generally similar within each site during the study period and there were no largescale consumer commercials directly targeting HepB vaccination among patients with diabetes during the study period at both sites. Therefore, it was unlikely that the observed increase in HepB vaccination at the intervention site could fully be attributed to the secular trend of patient demographics or vaccine promotion measures. Of note, after the conclusion of this study, the control site issued an electronic alert in April 2017 to prompt for patients with diabetes to receive HepB vaccines.

Since both provider reminders and the alert were provider-level interventions at the point of care, they would unlikely have an impact on the vaccine uptake among patients who did not have an outpatient encounter during the study period. Therefore, we conducted a post-hoc sensitivity analysis on those who had at least one outpatient visit during the assessment periods. The estimated RRRs in the sensitivity analysis were similar to that among the overall study sample and the effect of the intervention remained significant. Although the intervention effect on the third dose completion was statistically significant, the increase was smaller than that of the initiation rate. This suggested that additional patient outreach programs for vaccine series completion may be needed.

This study had several strengths. This was a large population-based study that assessed the potential impact of electronic provider reminders and alert on HepB vaccine uptake among adults with diabetes. The vaccination records were ascertained through a comprehensive EMR system at a large MCO, which mitigated recall bias that is often inherited in many survey studies that largely rely on patient self-reported vaccination data. Therefore, the coverage rate estimated in this insured study sample may not be directly compared with that reported in the 2014 national survey using self-reported data. By using EMR data, we included all eligible individuals in the analysis, which minimized selection bias potentially caused by low response rates or the use of a convenient survey sample. We also used a control group and conducted DID analysis to adjust for time varying confounders within each group and time varying confounders that occurred in both intervention and control groups.

This study had a few limitations. First, the records for those individuals who received HepB vaccine prior to their enrollment into the KPSC health plan or who received the vaccine at a non-KP facility during the study period may not have been complete. Of note, vaccines received outside of KP may have been entered into the EMR, at the discretion of the medical provider. Since the US instituted universal infant HepB vaccine in 1991, individuals who were born in or after 1991 may have received the 3-dose HepB childhood vaccine series. As there were less than 5% of the total study population who were born in or after 1991, we excluded those individuals from the analyses. Although KPSC and KPNC health plan members were unlikely to obtain vaccines at non-KP facilities, some members may have been misclassified as non-recipients if they did receive the vaccine at a non-KP facility, possibly resulting in underestimated vaccination rates. This potential bias could have occurred in both the pre- and post- implementation periods. However, we anticipated that the rate for misclassification was unlikely to vary substantially during the study period given the similar demographics distribution within each site over time.

The study was conducted in a large MCO where patients with diabetes can receive the HepB vaccine at no out-of-pocket cost during a free nurse visit or at a physician visit with a small visit co-pay. In other health care settings where patients may pay a high out-of-pocket co-pay for vaccination, such an intervention may not have had a similar significant impact on the vaccination rate.

## 5. Conclusions

Our findings indicated that EMR reminders and electronic alerts had an immediate high impact on HepB vaccination rate among adults with diabetes, while additional effort may be needed to prevent effect waning over time. The subsequent adoption of this intervention in the control site suggested that, as more health

systems adopt EMR and explore the meaningful use of EMR in patient care, use of these physician decision support tools to enhance patient wellness and preventive care utilization should be feasible.

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