An Online Spaced-Education Game Among Clinicians Improves Their Patients’ Time to Blood Pressure Control
A Randomized Controlled Trial

B. Price Kerfoot, MD, EdM*; Alexander Turchin, MD, MS*; Eugene Breydo, PhD; David Gagnon, MD, MPH, PhD; Paul R. Conlin, MD

Background—Many patients with high blood pressure (BP) do not have antihypertensive medications appropriately intensified at clinician visits. We investigated whether an online spaced-education (SE) game among primary care clinicians can decrease time to BP target among their hypertensive patients.

Methods and Results—A 2-arm randomized trial was conducted over 52 weeks among primary care clinicians at 8 hospitals. Educational content consisted of 32 validated multiple-choice questions with explanations on hypertension management. Providers were randomized into 2 groups: SE clinicians were enrolled in the game, whereas control clinicians received identical educational content in an online posting. SE game clinicians were e-mailed 1 question every 3 days. Adaptive game mechanics resent questions in 12 or 24 days if answered incorrectly or correctly, respectively. Clinicians retired questions by answering each correctly twice consecutively. Posting of relative performance among peers fostered competition. Primary outcome measure was time to BP target (<140/90 mm Hg). One hundred eleven clinicians enrolled. The SE game was completed by 87% of clinicians (48/55), whereas 84% of control clinicians (47/56) read the online posting. In multivariable analysis of 17 866 hypertensive periods among 14 336 patients, the hazard ratio for time to BP target in the SE game cohort was 1.043 (95% confidence interval, 1.007–1.081; P=0.018). The number of hypertensive episodes needed to treat to normalize one additional patient’s BP was 67.8. The number of clinicians needed to teach to achieve this was 0.43.

Conclusions—An online SE game among clinicians generated a modest but significant reduction in the time to BP target among their hypertensive patients.

Clinical Trial Registration—URL: http://www.clinicaltrials.gov. Unique identifier: NCT00904007.

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Key Words: educational technology • health services research • hypertension • medical education • patients
WHAT IS KNOWN

- Many patients with high blood pressure do not have anti-hypertensive medications appropriately intensified at clinician visits.
- Online spaced education has been shown to improve knowledge, boost learning retention, and improve clinical behavior among health professionals.

WHAT THE STUDY ADDS

- An online spaced education game improved clinicians’ knowledge of hypertension intensification and generated a modest but significant improvement in time to blood pressure target among their patients with hypertension.
- This study adds to the growing evidence that educational games may be effective tools to engage health professionals, boost learning, optimize practice patterns, and improve patient outcomes.

Methods

Setting and Participants
The randomized controlled trial was conducted at 8 Veterans Affairs (VA) medical centers in the New England region from March 2010 to April 2011. PCPs with 2 half-time clinical effort were eligible to enroll. Participants were recruited via e-mail. Adult patients of these providers were included in the analysis if they had ≥1 encounter with elevated BP (>140/90 mmHg). Patients were excluded if they had visits with clinicians from both intervention and control cohorts. The study received institutional review board approval and was registered at ClinicalTrials.gov (NCT00904007).

Development and Validation of Test Content
We assessed pre- and postgame hypertension knowledge among participants. Tests were developed based on a consensus of clinical practice guideline recommendations for hypertension management.17–19 The questions presented a clinical scenario and asked how the patient should be managed. Forty-four questions were independently content validated by 2 hypertension specialists, 1 physician educator and 1 education expert. Thirty-eight questions were selected and pilot tested by 33 internal medicine physicians. Twenty-four of these questions were selected for inclusion in the test based on item difficulty, point-biserial correlation, and clinical case scenarios with multiple-choice questions. On submitting an answer, the participant is presented with the correct answer and an explanation of the topic. The material is then represented in a cycled pattern to reinforce the content. We introduced several game mechanics to turn SE into a game, including competition among participants, adaptive content reinforcement based on performance, an appointment dynamic (one must engage at predefined times to take some action), and a progression dynamic (progress is displayed and measured by completing itemized tasks).15,16 We conducted a randomized, controlled trial to test the hypothesis that an SE game delivered to primary care providers (PCPs) on treatment of hypertensive patients will significantly decrease time to BP target (<140/90 mm Hg) among their patients.

Kuder–Richardson 20 score. Identical questions were used in both the pretest and posttest.

Development and Validation of SE Game Content
The educational content for the SE game was structured in a question-explanation format to take advantage of the testing effect. Thirty-two separate question-explanation items were developed, which focused on the same hypertension management issues addressed in the test questions but used different clinical scenarios. Detailed explanations were constructed to provide a take-home message, explain the answers, and provide references to clinical practice guideline documents.

Structure of the Game
We introduced several game mechanics to turn SE into a game, including competition among participants, adaptive content reinforcement based on performance (items were represented at different intervals based on whether they were answered correctly or incorrectly), an appointment dynamic (one must engage at predefined times to take some action), and a progression dynamic (progress is displayed and measured by completing itemized tasks).15,16 The game used an automated system that e-mailed questions (usual range, 1–2) every 3 days to participants. Each e-mail presented the clinical scenario and question on hypertension management. On clicking a hyperlink in the e-mail, a Web page opened that allowed participants to submit an answer, which was downloaded to a central server, and a Web page was then presented displaying the correct answer and a detailed explanation of the question content (for screenshot, please see the Data Supplement). The adaptive system repeated questions in 12 days if answered incorrectly and 24 days if answered correctly. The spacing intervals between repetitions were established based on psychology research findings to optimize long-term retention of learning.20,21 If a question was not answered within 12 days of delivery, it expired, was marked as answered incorrectly, and was cycled back to the clinician as above (appointment dynamic). If a question was correctly answered twice on consecutive presentations, it was retired from the SE game (progression dynamic).15 The goal of the SE game was to retire all 32 questions. To foster a sense of competition and community, participants were shown how many other participants had correctly answered a given question and how many had retired that question. The length of the SE game varied based on the rapidity with which each clinician answered and retired the SE questions.

Randomization and Interventions
PCPs were stratified by hospital and block randomized (block size=4) into 2 cohorts (Figure 1). All participants began the study simultaneously. During week 1, SE game clinicians began receiving interactive e-mails and control clinicians received a single e-mail linking to an online posting containing the identical educational content as the SE game cohort. This link could be accessed for study weeks 1 to 52 and was then removed. Clinicians in both cohorts received a reminder e-mail in week 2 if they had not accessed the SE game or online materials, respectively. A reminder e-mail with the link was sent to control clinicians again at week 40 of the study. The 24-item pre- and posttests were administered at enrollment and at week 52. No answers or feedback were given after test administration. Access to the SE game and online materials were blocked for both cohorts immediately prior to posttest administration. With each test, participants also completed survey questions on demographic characteristics and utilization of the educational materials. Participants received a $150 gift certificate to an online bookstore after submitting each test and up to 3.5 continuing medical education credits.

Clinical Data Sources
Data were extracted from Veterans Health Information Systems and Technology Architecture and regional pharmacy databases. Additional data were obtained from the VA National Patient Care Database Outpatient Clinic Files and the Patient Treatment Files, Austin Automation Center, TX.
Outcomes and Follow-Up

A unique hypertensive period served as the unit of analysis. A hypertensive period started on the first day during the study when a patient’s BP was elevated. It ended on the first subsequent day when it was <140/90 mm Hg or on the last day BP was recorded during the study.23 Duration of the hypertensive period (days) was the outcome measure. BP measurements obtained in the course of routine care were used to ascertain study outcomes, whether obtained by the PCP or at other clinic visits. These measurements were obtained from structured data (ie, BP recordings in the electronic medical record) and natural language processing of provider notes as previously described.22 If several measurements were recorded on the same day, the lowest mean arterial BP was used.

Time to BP target (<140/90 mm Hg) was the primary outcome because this is a sensitive assessment of the effect of a provider-oriented intervention.23 Furthermore, time-to-target is an important indicator of quality of hypertension care based on studies showing faster achievement of BP control is associated with lower rates of medication nonadherence. Each patient could contribute >1 hypertensive period because BP could fluctuate above and below the treatment target during the study period.

Hypertensive periods were included in the analysis if they contained an interim visit with a study provider and were not transient. Transient hypertensive periods were defined as BP normalization by the second measurement without antihypertensive medication intensification.28 This approach excludes short-term BP elevations that are independent of medical treatment such as acute pain or temporary medication nonadherence. Each patient could contribute >1 hypertensive period because BP could fluctuate above and below the treatment target during the study period.

Prespecified secondary outcomes included last BP recorded during the study and differences in PCPs’ postgame test scores. We also performed a post hoc analysis comparing patients based on their use of antihypertensive medications prior to the study.

Statistical Analysis

All participants who completed both the pretest and posttest were included in test score analysis. Test reliability was estimated with Cronbach α which assesses the systematic variance of a measure administered to a sample.26 Scores were analyzed with a 2-tailed t-test with SPSS 19.0 (Chicago, IL). Learning effect sizes were measured with Cohen d which expresses the difference between means in standard deviation units,27 with a 0.2 effect generally considered as small, 0.5 as moderate, and ≥0.8 as large.

Log-rank test was used to compare times to BP target between intervention and control groups. Marginal Cox proportional-hazard models for clustered data were used to estimate the association between the intervention and time to BP target while accounting for clustering within individual patients.28 A hazard ratio >1 favors the SE game intervention, whereas a hazard ratio <1 favors control.

Patients were associated with a study clinician based on the highest number of visits during the hypertensive period. Antihypertensive medication possession ratio was calculated from the pharmacy prescription fill data as the fraction of the number of days for the previous 12 months for which medication was supplied.29 Medication intensification was defined as an initiation of a new or an increase in the dose of an existing antihypertensive medication.30 Information on medication intensification and nonpharmacological lifestyle counseling was obtained using natural language processing of narrative provider notes.31,32 All of the natural language processing tools used in the study were revalidated on a random sample of narrative notes drawn from the study data set.

The models were adjusted for clinician factors (provider type, panel size, pre- and posttest scores, and prior SE participation) and patient factors (age, sex, history of diabetes mellitus and coronary artery disease, antihypertensive medication possession ratio, initial BP, number of classes of antihypertensive medications taken at study start, frequency of provider visits, frequency of antihypertensive medication intensification, and frequency of lifestyle [diet, exercise, and weight loss] counseling). To determine the relationship between the intervention and the last recorded BP, we constructed hierarchical multivariable mixed linear regression models with random intercepts to account for clustering within individual providers. The models also included the same confounders as the Cox proportional hazards models described above. We also calculated the number of hypertensive episodes needed to treat to normalize 1 BP by the median normalization duration for the control group using the methodology of Altman and Andersen.33 The number of clinicians needed to teach was calculated by dividing the number of hypertensive episodes needed to treat by the number of hypertensive episodes per provider. All calculations were performed using SAS 9.2 (SAS Institute Inc, Cary, NC) except where indicated.

Results

Of 303 PCPs invited to participate, 111 (37%) enrolled. Participants’ baseline demographic characteristics were similar between randomized cohorts (Table 1). All participants completed the pretest at enrollment, and 95% (52/55) and 93% (52/56) of SE game and control group clinicians completed the posttest, respectively (Figure 1). Cronbach α reliabilities of the pretest and posttest were 0.72 and 0.82, respectively. Mean pretest scores were similar for both cohorts: 58%
Table 1. Baseline Demographic Characteristics of Randomized Clinicians

<table>
<thead>
<tr>
<th>Provider Characteristics</th>
<th>SE Game</th>
<th>Controls</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants in trial</td>
<td>55</td>
<td>56</td>
<td>0.39</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>20 (36%)</td>
<td>18 (32%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>35 (64%)</td>
<td>38 (68%)</td>
<td></td>
</tr>
<tr>
<td>Provider type</td>
<td></td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Physician</td>
<td>33 (60%)</td>
<td>26 (46%)</td>
<td></td>
</tr>
<tr>
<td>Nurse practitioner</td>
<td>19 (35%)</td>
<td>24 (43%)</td>
<td></td>
</tr>
<tr>
<td>Physicians assistant</td>
<td>3 (5%)</td>
<td>6 (11%)</td>
<td></td>
</tr>
<tr>
<td>Hospital location</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedford, MA</td>
<td>6 (11%)</td>
<td>5 (9%)</td>
<td></td>
</tr>
<tr>
<td>Boston, MA</td>
<td>8 (15%)</td>
<td>10 (18%)</td>
<td></td>
</tr>
<tr>
<td>Manchester, NH</td>
<td>3 (5%)</td>
<td>2 (4%)</td>
<td></td>
</tr>
<tr>
<td>Northampton, MA</td>
<td>2 (4%)</td>
<td>2 (4%)</td>
<td></td>
</tr>
<tr>
<td>Providence, RI</td>
<td>5 (9%)</td>
<td>4 (7%)</td>
<td></td>
</tr>
<tr>
<td>Togus, ME</td>
<td>7 (13%)</td>
<td>7 (13%)</td>
<td></td>
</tr>
<tr>
<td>West Haven, CT</td>
<td>14 (25%)</td>
<td>16 (29%)</td>
<td></td>
</tr>
<tr>
<td>White River Junction, VT</td>
<td>10 (18%)</td>
<td>10 (18%)</td>
<td></td>
</tr>
<tr>
<td>Age (mean [SD])</td>
<td>50.5 (7.7)</td>
<td>53.1 (8.5)</td>
<td>0.38</td>
</tr>
<tr>
<td>Study patients in panel (mean [SD])</td>
<td>131 (54.7)</td>
<td>127 (54.8)</td>
<td>0.68</td>
</tr>
<tr>
<td>Total panel size (mean [SD] patients)</td>
<td>490 (158.5)</td>
<td>508 (159.0)</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Percentages may not total 100% because of rounding. SE indicates spaced education.

Study clinicians had 25,365 patients with hypertensive periods and ≥1 visit to a participating provider during the study period. Of these, 10,445 patients were excluded because BP elevations were transient and 584 were excluded because they had visits with clinicians from both intervention and control groups. The remaining 14,336 patients were included in the analysis, comprising 17,866 hypertensive periods (Tables 2 and 3). Given that randomization took place at the clinician level, characteristics of the patients of SE game and control clinicians not unexpectedly differed in small but significant respects (Table 2).

Primary Outcome

In univariate analysis, median time to BP target (<140/90 mmHg) was 129 days in the intervention and 134 days in the control group (P=0.46). Among patients taking antihypertensive medications at the start of the trial, the median time to BP target was 117 and 125 days for the SE game and control cohorts, respectively (P=0.022). In multivariable analyses that adjusted for patient differences between cohorts and patient clustering by provider, but excluded process measures that might mediate SE game effects, the hazard ratio for time to BP target was 1.043 (95% CI, 1.007–1.081; P=0.018) in the SE game group. We then added back prespecified process measures to the statistical model, with the expectation that statistical significance would be eliminated or reduced if these process measures mediated the SE game’s effect. Consistent with our hypothesis, the impact of the intervention was eliminated after addition of posttest scores (P=0.8683) and visit frequency (P=0.8956). The impact was reduced after addition of frequency of antihypertensive medication intensification (hazard ratio, 1.036; P=0.046). We obtained similar results in the analysis limited to the first hypertensive period for every patient (data not shown). After multivariate adjustment, the median time to BP target for all patients was 142 and 148 days for the SE game and control cohorts, respectively (P=0.018). Among patients taking antihypertensive medications at the start of the trial, the multivariate-adjusted median time to BP target was 137 and 145 days for the SE game and control cohorts, respectively (P=0.005). Other multivariate adjusted factors that affected time to BP target across all patients in both cohorts included patient sex, age, initial BP, comorbidities, medication adherence, PCPs’ panel size, and pretest scores, whether PCPs were physicians, and whether patients were taking antihypertensive medications at the start of the trial.

Table 2. Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients of SE Game Clinicians</th>
<th>Patients of Control Clinicians</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study patients, n</td>
<td>7224</td>
<td>7112</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>67.2 (12.8)</td>
<td>67.8 (13.0)</td>
<td>0.002</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>477 (6.6)</td>
<td>336 (4.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>eGFR, mean (SD), mL/min/1.73 m²</td>
<td>77.8 (21.3)</td>
<td>77.8 (21.4)</td>
<td>0.99</td>
</tr>
<tr>
<td>Baseline antihypertensive medicine classes, mean (SD)</td>
<td>1.7 (1.56)</td>
<td>1.8 (1.54)</td>
<td>0.0048</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>2496 (34.6)</td>
<td>2382 (33.5)</td>
<td>0.18</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>895 (12.4)</td>
<td>955 (13.4)</td>
<td>0.064</td>
</tr>
<tr>
<td>Starting SBP, mean (SD), mmHg</td>
<td>140.3 (17.4)</td>
<td>140.0 (17.1)</td>
<td>0.30</td>
</tr>
<tr>
<td>Starting DBP, mean (SD), mmHg</td>
<td>77.1 (11.7)</td>
<td>76.9 (11.7)</td>
<td>0.33</td>
</tr>
</tbody>
</table>

DBP indicates diastolic blood pressure; eGFR, estimated glomerular filtration rate; SBP, systolic blood pressure; and SE, spaced education.
of the study (Figure 2). Patients who were older, had higher systolic BP, and whose PCP was a physician had longer time to BP target.

**Secondary Outcomes**

In a subgroup analysis among patients taking antihypertensive medications at study onset, the hazard ratio for time to BP target was 1.060 favoring the SE game (P=0.0046, multivariate analysis). Among SE game clinicians, the number of hypertensive episodes needed to treat to normalize 1 additional patient’s BP was 67.8. To achieve this, the number of clinicians needed to teach with the SE game was 0.43. Thus, for each clinician who participated in the SE game, 2.3 additional patients achieved BP normalization during the study.

**Discussion**

The SE game improved clinicians’ knowledge of hypertension management and generated a modest but significant improvement in time to BP target among their hypertensive patients. This study is particularly noteworthy because it is the first to demonstrate that an online educational game among medical professionals can improve the health measures of their patients. Improvements in patients’ time to achieving BP control can be clinically important. Several studies have shown that patients who achieved faster BP control for weeks to months had tangible clinical benefits, including lower rates of stroke, cardiovascular events, and overall mortality.1,24,34 Our study showed an effect that was measured in days. Improved clinical outcomes that may result from such an intervention would likely be evident only across a large patient population.

As a method to increase clinicians’ long-term knowledge, the SE game was significantly more effective than providing the identical content as an online posting with e-mail reminders. Despite this large knowledge gain, there was a small improvement in time to BP control. Our modest findings highlight the substantial challenges in translating improvements in clinicians’ knowledge to changes in patients’ outcomes.35

Although this is a laudable goal, our study shows how difficult this is to achieve and adds evidence to the on-going discussion about the appropriate standards by which to judge educational programs.36

Some of the strengths to our study include the novelty of the SE game intervention, the inclusion of multiple PCPs from 8

<table>
<thead>
<tr>
<th>Table 3. Characteristics of Hypertensive Periods Experienced by Patients in Both Cohorts, Univariate Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>Hypertensive periods, n</td>
</tr>
<tr>
<td>Physician PCP, n (%)</td>
</tr>
<tr>
<td>Highest SBP, mean (SD), mm Hg</td>
</tr>
<tr>
<td>Highest DBP, mean (SD), mm Hg</td>
</tr>
<tr>
<td>Medication possession ratio, mean (SD)*</td>
</tr>
<tr>
<td>Time since study start, mean (SD), mo†</td>
</tr>
<tr>
<td>Monthly visits, mean (SD)</td>
</tr>
<tr>
<td>Monthly medication intensifications, mean (SD)</td>
</tr>
<tr>
<td>Monthly lifestyle counseling, mean (SD)</td>
</tr>
</tbody>
</table>

Individual patients can contribute >1 hypertensive period. DBP indicates diastolic blood pressure; PCP, primary care provider; SBP, systolic blood pressure; and SE, spaced education.

*Medication possession ratio is the fraction of the number of days for the previous 12 mo for which medication was supplied.

†Time between the beginning of the study period and the start of the hypertensive period.
VA medical centers, the size and scope of the patient population, the duration of follow-up, the usage of natural language processing to extract data from provider notes, and a control group in which participants received identical content but via a different method. Given that PCPs often have hundreds of patients in their panels, the clinical impact of an educational intervention to improve PCPs hypertension management can be substantially amplified across their practice. The number needed to teach is a novel yet simple outcome measure to capture this amplified clinical impact.

There are also several limitations to our study, including the recruitment of 37% of eligible PCPs and its restriction to northeastern VA hospitals where practice patterns may differ from other regions. Although we worked to assess all meaningful covariates in our analyses, some meaningful covariates may not have been assessed, and thus, the analyses may not fully account for the clustering of data within providers. The intervention cohort received more frequent e-mail notifications compared with the control group; we cannot exclude that these e-mail reminders rather than their content generated the improved hypertension outcomes in our study. A future study will assess if an SE game directed to patients rather than providers results in larger improvements in health outcome measures. Not unexpectedly, randomization at the clinician level led to imbalances in patient characteristics between study arms. We also analyzed surrogate outcomes and process measures in hypertension treatment. Further research is needed to assess the SE game’s impact on clinical outcomes, such as strokes and cardiovascular events.

In summary, our study demonstrates that an online SE game among PCPs can significantly reduce the time to BP target among their hypertensive patients. This study adds to the growing evidence that educational games may be effective tools to engage health professionals, boost learning, optimize practice patterns, and improve patient outcomes. Future efforts should focus on determining how to most effectively integrate game mechanics into the education of health professionals for the benefit of their patients.

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Disclosures
Dr Kerfoot is an equity owner and director of Qstream Inc, an online platform launched by Harvard University to host spaced education outside of its firewalls. No resources from Qstream were used to conduct this research. The other authors report no conflicts.

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